WELFARE OF THE LAYING HEN

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Edited by

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PREFACE

These Proceedings are the 27th in a series organized by the United Kingdom branch of the World's Poultry Science Association. The Symposium Committee introduced some changes from previous meetings. Firstly, the chosen topic was broader and included several scientific disciplines. As a consequence, the programme was longer and extended over 3 days instead of the usual 2. Secondly, the topic was chosen because the publication of the Proceedings would precede a review of the EU Welfare of Laying Hens Directive and it was intended that the Symposium would include the most recent scientific information for the review body. Thirdly, the panel of scientific speakers was extended to include views from Government, European veterinarians, World Trade implications, retailers, consumers and producers. It is hoped that this wide panel of experts will help the reader to better understand the issues arising from the demand for higher standards of welfare for laying hens. The extended group of speakers, referred to as the Stakeholders, illustrated some of the conflicting issues facing the UK and European egg industries as 2012 approaches. Will Europe be able to produce eating eggs on a competitive basis with the rest of the world? Will higher welfare standards in Europe lead to increased imports from non-EC sources where welfare standards may be lower? How can we reconcile public demand for higher welfare standards with increased production costs, with the implication that whilst we might demand improvements in welfare, purchasers may be unable or unwilling to buy eggs from the 'improved systems'? The stakeholder papers highlight the challenges and anticipated problems that lie ahead.

A quick review of the scientific papers shows the extent to which the knowledge base of hen welfare has increased in recent years. The emphasis on hen welfare research during and since the early 1990s has resulted in a large increase in papers published in the last decade, many of which are cited in the Reference sections of the chapters in this Volume.

The scientific section of the Symposium began with two comprehensive reviews before turning to more specific topics. The sessions dealing with perception and cognition, genetic influences and behaviour perhaps illustrate best the advances made in our understanding of laying hen welfare. The issues of stockmanship and the quality of the environment have also received considerable attention in recent times and there were reminders that disease can pose serious challenges to the welfare status of hens. These latter aspects may assume even greater importance with the development and introduction of alternative systems of egg production. Lastly, transportation and slaughter were considered. Almost all hens will have been transported at least three times during their life – hatchery to rearing farm, then on to the production unit and finally from there to the slaughter plant. The relatively short time spent in transit should not encourage all those concerned to overlook the severe welfare challenges that exist. It is also

incumbent upon those involved to ensure that all birds are humanely treated at the abattoir.

The Symposium concluded with a Summary session. This highlighted some of the new information that was presented and also identified areas where more research was required.

It is a matter of regret that two speakers were unable to submit papers for inclusion in these Proceedings. Both papers had associations with veterinary matters and their absence misses an opportunity to represent and reinforce views expressed at the Symposium that health and disease is an integral aspect of hen welfare and will be one focus of attention in the alternatives to the battery cage system.

I am indebted to the Organizing Committee for their contributions to the Symposium and trust that all the delegates and those readers who resort to these Proceedings will feel that the original objectives were attained.

Organizing committee: G.C. Perry (Chairman); L. Craig; P.M. Hocking; R.B. Jones; C. Le Sueur; M.A. Mitchell; C.J. Nicol; D.G. Parsons; J.A. Parsons; N.B. Prescott; A. Walker; C.M. Wathes

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CHAPTER 1
The importance of welfare

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ABSTRACT

To whom are high standards of animal welfare important? They are important to consumers (more to some than others), to farmers and to the animals themselves. Although we have no more direct access to the minds of other humans than to the minds of hens, observations indicate that the typical consumer in the UK believes that farm animals can suffer if not cared for well, and that he or she does not like to think that this might happen in the production of his or her food. Farmers also share these concerns but have an additional interest in high standards of welfare for their animals because these correlate, at least to some extent, with good health, high productivity, improved marketability and profitability. For the animals themselves, if we assume that their minds, like our own, provide the conscious awareness of pleasant and unpleasant feelings associated with brain states induced by various sensory inputs and cognitive processes; welfare – the balance of the complex interaction of these feelings throughout their lives – is not just important, it is absolutely all that matters. The concern that animals should not have to endure unpleasant feelings is what animal welfare is all about. In taking increasing control of animals' lives through selective breeding and through the imposition of particular husbandry systems, we have acquired a great responsibility for the quality of their feelings. The welfare of vast numbers of animals – now and into the future – depends upon how we, as a society, prioritize and tackle this responsibility.

Through evolution, species have adapted to exploit an extraordinary range of niches. Despite the extreme demands of some of these niches, there are animals that not only survive, but even thrive, in seemingly adverse conditions. Nevertheless, there are limits to adaptability. Modern laying hens have been selected for outstanding rates of production, and husbandry systems generally involve shaping the environment to help maximize this. However, in recent years, increasing emphasis has been placed on selection for welfare.

I have been asked to address, in this chapter, the *importance* of welfare. This is an interesting assignment: the implicit question – what is the importance of animal welfare? – is an intriguing one. This would not be the case if we all, regardless of background, age, sex, nationality or lifestyle, shared a common understanding and held exactly the same views on the subject, but clearly we do not. In fact, there appears to be a very considerable diversity of opinion about the importance of animal welfare, both among individuals and among the positions adopted by nations. The latter is, or

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certainly has been, a significant factor in inhibiting developments for farm animal welfare since, in a free market, global or otherwise, it is hard for producers who pursue the highest welfare standards to compete economically with those who do not.

We – now more than 6 billion of us and with a population that is continuing to grow rapidly – inhabit a small planet with a finite annual productivity of organic matter (food) limited largely by the sunlight falling on it. The annual terrestrial production of organic matter is about 150 petagrams (Vitousek *et al.*, 1986; IUCN/UNEP/WWF, 1991), which is equivalent to around 500×10^{15} kcal/year. To a remarkable extent, we now influence the apportionment of this resource amongst animal species. It has been estimated that we share the planet with some 30 million other species, and tens of thousands of these are generally assumed to be sentient (there are, for example, more than 20,000 species of terrestrial vertebrates). Managing this situation – (i) meeting the requirements of the still very rapidly growing human population, whilst (ii) protecting biodiversity and (iii) protecting the welfare interests of other sentient species (at least those for which we are responsible) in this closed system – presents a very daunting challenge.

Why should we be concerned about protecting the welfare interests of animals and, more specifically in the context of this book, of poultry? This chapter will discuss the importance of animal welfare by addressing six questions: To whom is it important? What is it? Since when has it been important? What is the biological basis for concern for it? Why is it important? and How important is it?

TO WHOM IS WELFARE IMPORTANT?

There are three main parties to whom welfare is important. First and foremost, it is important to the hens themselves and, largely because of this, it is important also to farmers, to consumers and to the public in general. As far as the hens are concerned, I would argue that good welfare is not just of some interest but that it is the *only* thing that matters to them. If a hen's mind, like ours, provides the conscious awareness of pleasant and unpleasant feelings (associated with brain states induced by various sensory inputs and cognitive processes), welfare – the balance of the complex mixture and interaction of these feelings – is all that matters.

Although we may not have any better access to the minds of other humans than to the minds of hens, perhaps it is fair to observe that the typical consumer in the UK believes that farm animals can suffer if not cared for well and that he or she does not wish this to happen. The problem is that whilst this might summarize the position of a very large majority of consumers, there is great variation (within and between nations) in *how* important the matter is taken to be, and great variation also in opinions and expectations about what constitutes 'caring for animals well'. Housing that some people believe to be well-designed to meet the welfare requirements of hens may appall others. As for the farmers' perspective, they share the consumers' view about not wishing to cause suffering but have an additional interest in high welfare standards because these correlate, at least up to a point, with productivity (e.g. animals in poor condition will not be maximally productive) and, in some cases, with marketability and profitability.

WHAT IS WELFARE?

Welfare is one of those words that, at least in common use, often represents an assortment of vague notions. These may be to do with health, pleasant feelings, pastoral harmony or other concepts (see Fraser *et al*., 1997). Like 'freedom' – another loose idea that we are all in favour of for ourselves – the concept almost always needs to be more tightly delineated before it can be put to any sensible use in debate, let alone practice.

Prior to becoming a member of the Royal College of Veterinary Surgeons, and thus being permitted to diagnose and treat animal diseases in the UK, all candidates must make a solemn declaration: '… that my constant endeavour will be to ensure the welfare of animals committed to my care'. The phrases 'constant endeavour' and 'committed to my care', are clear and fairly unambiguous; but I suspect that the understanding of 'welfare of animals' – despite the pre-eminence it has always been given by the veterinary profession in this way – has varied between individuals and with time.

My own view is that welfare is about the balance of the quality, throughout life, of the complex mix of feelings associated with brain states induced by various sensory inputs and cognitive processes. As such, although about feelings, it is clearly related to states of physical health because diseases and injuries can affect feelings. However, concern for welfare does not merely correspond to concern for health, since one can have concern for health without having any concern for welfare (as, for example, gardeners do for their plants). Concern for welfare is for the animal's feelings (present and future) and we reserve the term 'welfare' for animals because we believe that only animals have feelings.

So what do we know about hens' feelings? We cannot know how hens feel – how it feels to be a hen – we can only make inferences based on our assessment of their physical state and behaviour, taking into account our knowledge of their neural capacities and in the light of our own experiences. In view of the obvious difficulties, it is appropriate to be cautious about making such inferences. In interacting with other humans we make inferences about feelings all the time but, in this case, whilst we cannot be certain that sensory stimuli and emotive thoughts feel the same to us as they do to other people, the fact that we share the same brain design and that verbal reports are often consistent with our own experiences, makes this quite plausible. To make inferences about how life feels for birds requires a very much greater inferential leap. Our last common ancestor with birds was a primitive anapsid reptile that lived about 300 million years ago. At that stage of their evolution, our distant ancestors' brains were relatively basic: many neuroanatomical developments have occurred in both hen and human lineages since that time.

Avian and mammalian brains have thus evolved along separate paths for a very long time. So, although there have been remarkable advances in knowledge of the specific brain regions, and even circuitry, involved in the generation of feelings in humans and in which capacities for feelings may be lost when specific areas are damaged (e.g. Damasio, 1999, 2003), and although this knowledge offers a possible approach to speculation about feelings in other mammals, this is complicated, if not precluded, in birds, because of the fundamental differences, particularly in the anatomy of the forebrain.

To conclude this section, welfare is about feelings. Feelings are subjective and

we cannot know for certain, or easily test our inferences about, how animals feel. This is a fact that we just have to accept. Nevertheless, knowledge of the neural basis of feelings is advancing rapidly and it seems reasonable to suppose that, in time, the bases for our inferences about the feelings experienced by hens and other animals may become firmer. With our present, limited, state of knowledge, it is reasonable to suppose that welfare – the balance of feelings – is very important (is all that matters) to hens.

SINCE WHEN HAS WELFARE BEEN IMPORTANT?

Life on earth began some 4 billion years ago. If sentience evolved with the vertebrates (with the exception of the common octopus, *Octopus vulgaris*, this is where the line is drawn in the Animals (Scientific Procedures) Act 1986), there may have been sentient species – animals that could suffer – for the last 450 million years or so. Furthermore, if this is so, then there is no doubt that unimaginably vast numbers will have suffered appallingly, bearing in mind, to quote Darwin (1859), that:

> each organic being is striving to increase at a geometrical ratio; that each at some period of its life, during some season of the year, during each generation or at intervals, has to struggle for life and to suffer great destruction.

However, concern for the welfare – the feelings – of other species has arisen only very recently in evolution. Although some non-human animal species may show behaviours suggestive of feelings akin to those in humans that are the emotional drivers for concern for animal welfare, before the evolution of humans there were no brains on earth in which the concept of animal welfare could germinate or reside. The emergence of our own species, *Homo sapiens*, is obscure but it may have occurred only within the last few hundred thousand years (Carroll, 2003). Concern for the welfare of farm animals may be as old as farming – about 10,000 years – but concern for welfare is not, in itself, much use unless combined with knowledge of how to prevent or alleviate the problems, and it is likely that very many welfare-costly mistakes were made in the early days of stock husbandry. The developments in knowledge and technology that have enabled such significant interventions for animal welfare as providing nutritionally balanced diets and treating and preventing infections have, for the most part, been very much more recent.

Only in the last 100 years or so, and largely in the latter stages of this period, has the subject begun to receive concerted scientific, ethical and legal attention. The agreement reached by the European Heads of State at the Amsterdam Summit (June 1997) to make provision in the Treaty of Rome (which established the European Community in 1957) to

> … ensure improved protection and respect for the welfare of animals as sentient beings

reflects the significant point in the progress of western culture that has been reached through this attention. Perhaps only the most curmudgeonly would argue that the agreement could have been better worded (*… for the welfare of sentient animals*).

WHAT IS THE BIOLOGICAL BASIS FOR CONCERN FOR WELFARE?

It is interesting to speculate on how the human tendency for concern for animal welfare may have arisen. What is its biological basis? The question is of interest because the answers may be relevant in explaining why there is such a wide variation in views about animal welfare, and in trying to promote a better consensus worldwide. Various possibilities about the biological origins of concern for animal welfare can be proposed.

- It may have arisen as an *adaptation*. This could have occurred if, for example, farmers with a genetic tendency to empathize with the feelings of their stock had reaped such evolutionary advantages as a result of their better stockmanship that their genetic tendency for animal empathy spread widely during human evolution.
- It could be a manifestation of *imprecise focusing* of the motivation to care for offspring or other members of a social group. Evolution has equipped us, and many other animals, with powerful motivation to care for our offspring. The concern of humans for the welfare of other animals might be due to the triggering of this motivation, but by non-conspecifics, as can happen in non-humans; as for example when females of one species rear or tend the offspring of others. This occasionally occurs in the wild but can easily be engineered in captivity (for example, de Waal (2001) describes the case of a tiger reared by a bitch in an Indian zoo). There is evidence, therefore, that the evolutionarily important motivation to care for offspring can easily be 'tricked': it is powerful but can be remarkably indiscriminate.
- Alternatively, the origins of concern for animal welfare may be *cultural* and linked to our (recent) increase in knowledge about biology and about feelings, and to the associated clarification of our ethical tenets.

The first of these possibilities seems less likely than the other two, but perhaps all three factors may have played a part in leading us to the point at which concern for animal welfare, or at least the potential for this concern, is quite widespread and, apparently, readily triggered.

WHY IS WELFARE IMPORTANT?

As argued above, to the hen, welfare is all that matters – there is nothing else. To the farmer, the hen's good welfare is important because it matters to the hen; because, within limits, there is a positive correlation between good welfare and productivity; and because, where consumers demand high welfare standards, it can lead to benefits in terms of profitability. Finally, good animal welfare is important to (some) consumers because: (i) the potential for strong motivation for the welfare of (some) other animals appears to be part of human biology; (ii) many cultural/religious traditions encourage efforts to care for animals; and (iii) there is a growing consensus about the importance of good welfare based on a greater understanding of animals and of our ethical responsibilities for them.

HOW IMPORTANT IS WELFARE?

It is meaningless to discuss how important good welfare is to animals: as argued above, for those animals whose minds provide conscious awareness of pleasant and unpleasant feelings, how they feel is all that matters to them. Unlike humans, other animals pursue no projects against which their interest in their good welfare might be compared. It is possible, on the other hand, to assess the relative importance of some of the factors that contribute to animals' good welfare by measuring preferences and strength of motivation for (or of aversion to) various commodities. There has been considerable interest in this approach in the last three decades. For example, in a recent study, Cooper and Appleby (2003) concluded that hens place a higher value on gaining access to a nest site prior to egg-laying than they do on gaining access to food after 4 hours' fasting.

There is no objective arbiter, however, as to the importance of animal welfare in general or with regards to particulars such as, for example, the importance – in the light of the Cooper and Appleby's finding (see above) – of providing nest sites for laying hens. The importance of animal welfare to each of us is that which we assign to it, and its importance to society is established by society as a whole through the stances it adopts and the legislation it sets.

As understanding of the science of animal welfare has developed, so too has the importance that society has come to attach to the pursuit of high welfare standards.

THE WAY FORWARD

Major advances in animal welfare will come through scientific developments. Animal welfare science is important, not just because it provides crucial information about animals' needs and how these needs can be met, but also because it can provide reliable information for society, and it is the public who ultimately dictate welfare standards. In the long run, a better global consensus about the importance of animal welfare is the key to avoiding the economically corrosive effects of cheap, poor-welfare systems and to encouraging the development of modern welfare-friendly systems. Science will help to establish this global consensus.

It is a difficult branch of science and one that is still in its infancy. Efforts to gain further insight into animals' feelings through the study of the neural machinery involved in generating feelings, and through behavioural studies that inform us about the kinds of phenomena of which animals are aware and about their responses to them – insights that are crucial if the welfare needs of animals are to be properly met – are likely also to influence public perceptions about the importance of animal welfare.

The concern that animals should not have to endure unpleasant feelings is what animal welfare is all about. In taking increasing control of farm animals' lives through selective breeding and through imposition of particular husbandry systems, we have acquired a great responsibility for the quality of their lives. The welfare of vast numbers of animals – now and far into the future – depends upon how we, as a society, prioritize and tackle this responsibility.

Through evolution, species have adapted to exploit an extraordinary range of niches. Despite the extreme demands of some of these niches, there are animals

that not only survive, but even thrive, in them. Nevertheless, there are limits to adaptability. Modern layers have been selected for their high rates of production, and husbandry systems generally involve shaping the environment to help maximize this. However, in recent years, increasing emphasis has been placed on selection for welfare-relevant traits and on determining and providing the environmental needs for good welfare. We must strive for world-wide agreement that efforts in these directions are of central importance in the continuing development of the animal production industry.

REFERENCES

Carroll, S.B. (2003) Genetics and the making of *Homo sapiens*. *Nature* 422, 849–857.

Cooper, J.J. and Appleby, M.C. (2003) The value of environmental resources to domestic hens: a comparison of the work-rate for food and for nests as a function of time. *Animal Welfare* 12, 39–52.

Damasio, A. (1999) *The Feeling of What Happens*. William Heinemann, London.

Damasio, A. (2003) *Looking for Spinoza: Joy, Sorrow and the Feeling Brain*. William Heinemann, London.

Darwin, C. (1859) *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life.* John Murray, London.

De Waal, F. (2001) *The Ape and the Sushi Master: Cultural Reflections of a Primatologist*. Paul Allen, London.

Fraser, D., Weary, D.M., Pajor, E.A. and Milligan, B.N. (1997) A scientific conception of animal welfare that reflects ethical concerns. *Animal Welfare* 6, 187–205.

IUCN/UNEP/WWF (1991) *Caring for the Earth: a Strategy for Sustainable Living*. IUCN, UNEP, WWF, Gland, Switzerland.

Vitousek, P.M., Ehrlich, P.R., Ehrlich, A.H. and Matson, P.A. (1986) Human appropriation of the products of photosynthesis. *BioScience* 36, 368–373.

PART I
The stakeholders

CHAPTER 2
Hen welfare: the consumers' perspective

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ABSTRACT

Against a backdrop of falling egg consumption, cholesterol and salmonella scares, the UK egg industry has positioned itself as an efficient and competitive industry which is not reliant on subsidies. The introduction of the Lion scheme, along with its associated promotional campaign and greater innovation on the part of suppliers, seems to have arrested the decline in egg consumption in the UK. It is suggested that consumers in the UK are more concerned than ever about how their food is produced in terms of quality and food safety, and also demand assurances on animal welfare. Information on welfare assurance, method of production and country of origin is now provided on food packaging labels. The proliferation and promotion of quality assurance schemes in the food industry are intended to build consumer trust in the quality of the product and to encourage consumers to seek out these products in the market outlets.

Egg producers are now faced with the task of ensuring higher welfare standards to comply with the regulations laid down in the EU Directive 1999/74/EC. Whilst improved hen welfare is always desirable, the literature reviewed suggests that the resultant internalized cost of production, along with increasing trade liberalization under the auspices of the WTO, will have a considerable effect on the industry. Studies have shown that this will place the EU and UK egg industry in an uncompetitive position for both shell eggs and egg products. The concern is that these directives will encourage increased production of eggs in non-EU countries and increase the volume of imported eggs into the EU and UK. These eggs may have been subjected to less restrictive production controls, using products banned in the EU due to food safety concerns, leading to an effective shift in welfare problems from one region to another. Although there has been an increase in sales of eggs from alternative production systems in the UK, the larger share of the retail market in packaged eggs and eggs sold for catering purposes is represented by the output from caged hens. Those consumers who are prepared to pay more for what they perceive to be higher standards of animal welfare already have the opportunity to do so, through the availability of barn, free-range and organic eggs.

This chapter investigates whether this legislation is customer-led and evaluates the factors influencing consumer choice and attitudes towards the purchase of eggs. It questions whether consumers are aware that the various production systems have different costs attached and whether they are prepared to pay for these increased costs. It highlights that whilst consumers indicate that an important factor in their buying decision is the type of production system the eggs came from, their knowledge of each system is limited and their views are not necessarily reflected in their purchasing behaviour. The chapter considers the many challenges that these factors pose to the industry.

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SETTING THE SCENE

Consolidation is a key feature in the UK egg industry and mirrors developments in other food sectors in the search for economies of scale and for ways to increase or maintain market share. It also enhances the ability to develop innovative products in an increasingly competitive environment.

The number of birds in the national flock is declining each year, while the number of laying units is tending towards fewer but larger units (Poultry World, 2001), where over three-quarters of the UK laying flock are now housed in units of over 20,000 birds. Almost three-quarters of hen eggs (72%) are produced within the caged house system, with the remaining shell eggs coming from free-range (23%) and barn hens (5%) (BEIC, 2002b).

THE LION MARK

The Lion scheme was reintroduced in 1998 with a strict code of practice, which incorporates both farm assurance and quality assurance, in order to build brand value and regain trust and loyalty. The Lion scheme, along with its associated promotional campaign and greater innovation on the part of suppliers, seems to have arrested the earlier decline in egg consumption in the UK and seeks to benefit all parties in the supply chain. For consumers the scheme provides the assurance of less risk of salmonella poisoning, fresher eggs, and eggs produced to more rigorous production standards. Indeed, it has been reported to achieve a high level of recognition (75%) and understanding by consumers (Parrott, 2001; BEIS, 2002; Serati-Shirazi, 2003). For the industry, it not only results in a reduction in salmonella, but also attempts to develop trust and loyalty in the home-produced product against the threat of cheaper egg imports from other countries. Since its high-profile launch, there has been an increase in the sales of eggs. It could be questioned whether this increase in sales is due to the trust placed in the Lion brand or through exposure to the intense advertising campaign. For retailers, the Lion scheme provides them with an insurance, allowing them to offer their customers the promise of due diligence in the food production and supply process, through improved food safety and traceability.

LEGISLATION AND COMPETITIVENESS

Egg producers are now faced with the task of ensuring higher welfare standards in accordance with the regulations contained in EU directive 1999/74/EC. Whilst improved hen welfare is desirable, it is suggested that the consequent internalized cost of production, along with increasing trade liberalization under the aegis of the WTO, will have a large effect on the industry. Studies have shown that this will put the EU and UK egg industries into an uncompetitive position for both shell eggs and processed egg products (BEIC, 2002a; van Horne and Bondt, 2003). Although fundamentally an efficient industry, egg production in the UK has higher production costs (approximately 40% higher than in the USA) from 'cost internalization' driven by legislation and consumer demands. It is estimated (BEIC, 2002a) that extra costs incurred by 2012 will result in an additional production cost of 18.94 pence per dozen. The additional costs imposed by EU/UK legislation are

concerned with food safety, animal welfare and the environment. The feeding of mammalian meat and bone meal is prohibited by EU law but this is not the case in the USA and Brazil. Testing for salmonella, shell marking, costs of disposal of end of lay hens, prohibition of low-grade cooking oils in animal feeds and the use of therapeutic antibiotics all contribute to the distortion of trade. The legislation associated with animal welfare through the specification of cage space requirements and prohibition of beak trimming in the UK, and environmental regulations, will all increase the cost of production. Further additional costs demanded by the UK retailers and consumers add to this distortion, which include the prohibition of 'tallow' in egg layer diets, the withdrawal of some egg yolk colourants, prohibition of moulting, the requirement for non-genetically modified feeds and the costs associated with quality assurance schemes.

The industry will face pressure from increased imports of eggs, and these imported eggs will most likely make their way into the processing sector. This is a growing sector of the business. The split of the market volume for eggs in 2001 was estimated to be 60.5% retail sector, 21% catering sector and 18.5% manufacturing processing sector (industry estimate, BEIC, 2001); however, there has been a recent revival in the volume of retail sales to 65% of market volume (BEIC, 2002b; Mintel, 2002).

The concern is that these directives will further encourage the production of eggs in countries outside the EU and increase the volume of imported eggs into the EU and UK. These may be produced under less restrictive production controls and using products that have been banned in the EU due to food safety concerns. In effect, looking at the global picture, it is suggested that stricter legal standards within the EU will not lead to an improvement in animal welfare, but to a regional shift of the problems (Wolfram *et al.*, 2002), as minimum animal welfare requirements are not met in other countries.

The caged hen egg sector faces the greatest competitive disadvantage and faces the greatest danger of substitution by imported eggs. This substitution is likely to be more focused on the liquid and dried egg sector, since transportation costs from non-EU country markets to the EU are lower than those for shell eggs, and the origin of these is less important for consumers. Heil and Flock (2002) suggest that as long as consumers (or customers) have access to eggs or egg products from cheaper sources, they will probably react in the same way as that observed in Switzerland, where eggs bought for domestic use are almost all high-welfare eggs, whereas the egg product market mainly comes from imported battery-hen-produced eggs.

Price and microbiological properties are the key issues for the food service and processing industries. Factors such as country of origin, housing system, cage stocking density and other welfare provisions are not seen to affect the functional quality of egg powders and therefore have no place in sales negotiations (BEIC, 2000a; van Horne and Bondt, 2003). On the retail side, the multiple chain grocers account for three-quarters of retail sales of shell eggs and the eggs sold are almost entirely produced in the UK. Whilst there is an increase in sales volumes of eggs from alternative production systems in the UK, the larger share of retail eggs and eggs for catering purposes is from caged hens. A preference for retailers and caterers to use eggs from the Lion scheme could offer a competitive advantage for home-produced eggs.

In the UK, those consumers who are prepared to pay for what they perceive

to be higher standards of animal welfare already have the opportunity to do so, through the availability of barn, free-range and organic eggs. A further increase in market share in this sector is anticipated and is expected to continue to rise.

LABELLING

At present there is mandatory labelling showing production methods for EC-produced shell eggs; however, it is unlikely that this will extend to imported eggs because of WTO compatibility and technical barriers to trade. It could be hypothesized that better labelling would help to increase and support demand for eggs from alternative systems. To what extent that 'better labelling' could be achieved is uncertain.

The introduction of a labelling code within the Lion scheme disallows certain terms and images which may have wrongly implied that eggs had been produced under free-range conditions, such as the terms 'farm fresh' and 'country fresh'. Eggs from hens in laying cages are now labelled as 'eggs from caged hens'. Consumer research (Mintel, 2002) suggests that those consumers who previously stated that they bought 'farm fresh' eggs now claim to buy 'free-range' eggs. The concern that consumers may have been confused into buying cage-produced eggs when they really wanted free-range pinpointed the need for clearer labelling. The colour coding on packaging on own-label eggs is hoped to alleviate this problem; the colour green is used for free-range eggs, brown for barn eggs, and white represents eggs from hens in laying cages.

With respect to egg products, the labelling of eggs is ineffective, as their provenance is lost when they are used for processing. Improved labelling would not help the invisibility and lack of segregation of egg products and may indeed increase the market for low-welfare eggs despite the consumers' stated opposition to battery cages. Therefore labelling may not be effective in encouraging consumers to shift to buying from alternative systems but could be useful for traceability and ensuring due diligence (RSPCA, 2001).

CONSUMERS' BUYING BEHAVIOUR

It is suggested that consumers in the UK are more discerning than ever about how their food is produced in terms of quality, food safety and animal welfare. Information on welfare assurance, method of production and country of origin is provided on food packaging labels. The proliferation and promotion of quality assurance schemes in the food industry is intended to build consumer trust in the quality of the product and to encourage consumers to seek out these products in the market outlets.

Many households are financially better off and therefore not as price-driven as the households of two decades ago. Consumers are concerned with animal welfare and with the perception that an animal should have had a 'decent life', being able to roam freely outdoors in green fields. It could be questioned whether the recent hen welfare legislation is customer-led. The tendency for people to eat out more often, rather than at home, places power in the hands of catering suppliers who are keen to buy on price/quality alone with scant regard to where or how the

product was produced as long as safety is inherent. The buying behaviour of Local Education Authorities is a prime example of this, where egg purchasing criteria are for value (price and quality), with very limited guidance on seeking eggs from the Lion scheme (M. Swannick, Staffordshire Women's Farming Union, 2003, personal communication).

The consumer's choice is influenced by several different factors, which include cultural, social, personal and psychological factors, Kotler (2003) states that it is the marketer's task to understand what happens in the buyer's consciousness between the arrival of outside stimuli and purchase decisions. The different types of beliefs and cultures can influence our values and can be very influential in encouraging or discouraging consumption of certain products. Little happens to the actual egg once it has been laid by the hen and subsequently reaches the home of the consumer. The factors influencing buying behaviour may be related to a particular method of production (i.e. free-range, organic etc.) or may be due to the impact of packaging on the consumer, price, or there may be very limited decision making involved and any egg type would satisfy the consumer's needs. Evidence from primary research (Parrott, 2001) suggests that consumer buying behaviour is based on emotional responses, involving intangible benefits, and may not always take place at an entirely rational and conscious level. Whereas a number of respondents expressed rational overt reasons for wanting to buy free-range eggs, they actually bought shell eggs to meet functional demands. Thus, latent factors are influencing buying behaviour.

There is the perception (Mintel, 2002) that battery-rearing conditions are not conducive to optimum quality, nutritionally rich, eggs and are more likely to produce unsafe food products, and that cages represent inhumane conditions in which to keep hens. As mentioned earlier, with almost three-quarters of hen eggs (72%) produced within the caged house system, it could be assumed that consumers are content with eggs from intensive systems. However, attitudes from consumers portray a different story, with more than 60% of consumers indicating that they buy free-range eggs (Mintel, 2002) and less than 40% admitting to purchasing eggs produced in laying cages.

Although not borne out in retail supply terms, this aspiration to purchase non-cage-produced eggs is gaining strength. There is generally a move to free-range eggs. Whether this is consumer-led or marketing-led is debatable, especially since there are growing numbers of retailers and fast food outlets who have decided not to supply caged eggs at all (Mintel, 2002; RSPCA, 2002) and an increasing demand for free-range and organic eggs by processors who release products under organic labels. Offering eggs from entirely alternative systems has been one area for retailers to exercise competitive positioning. This may be in order to have a point of difference and to move away from a commodity market to a more premium market as well as demonstrating their acknowledgement of the importance of corporate social responsibility.

Attractive egg packaging is used to differentiate the market and encourage consumers to upgrade the type of eggs they buy away from the value-line range. Exciting promotional campaigns associated with current film trends, linked promotions with other product endorsements, and collectable gifts are increasingly prevalent and offer an appealing alternative to traditional consumer buying behaviour and beliefs.

It has been suggested by De Chernatony and McDonald (1992) that the

consumer balances a brand choice with both rational and emotional needs, which are subsequently satisfied through the brand's identity. Attempts are made by processors and retailers to develop branding in eggs and poultry meat to incorporate the 'intangible values created by a badge of reassurance' (Southgate, 1994). In addition to the 'name, symbol, design or some combination which identifies the product having a sustainable differentiated advantage', the brand forms a bond between producer/manufacturer and the consumer. It allows the consumer to shop with confidence, and provides the manufacturer with higher volumes, higher margins and a guaranteed future demand.

A brand's value to a firm is influenced by customer loyalty to that brand. In order to compete effectively it should have the promise of authenticity and replicability, which allows the consumer to limit their choice in the decision-making process along with a value of reassurance. Intangible factors sought from the product are those which the consumer relies on and pays for. Loyalty shown by consumers may be segmented (Aaker, 1996) and used to target and position the products. Typical consumer segments emerging, which may have an influence on egg marketing, are suggested as:

- The price-conscious battery egg consumer – to whom an egg is just an egg.
- The apathetic battery egg consumer – expresses latent concern for bird welfare but is too busy to put this into practice.
- Soft free-range consumer – displays discerning tastes and a preference for natural foods (hoverers).
- Hardcore free-range egg consumers (see Fearne and Lavelle, 1996).

Tesco's own research has segmented its organic consumers into three groups:

- The devotees (9.9% of households).
- The dabblers (17.3% of households).
- The don't knows (72.8% of households) (IGD, 2002).

In the USA, trends in consumer priorities show further challenges and opportunities facing the food industry where, according to research studies, there are newly emerging consumer demands on the industry. These demands can be segmented into four areas:

- Taste rules – shoppers are less willing than ever to compromise on taste for the sake of health benefits.
- Self-medication, self-education – consumers remain confident in their ability to manage their health. Nutritional and herbal solutions are credible to consumers.
- Nutritional individualization – almost three-quarters of shoppers believe that everyone has different nutritional needs. Differing life stages and health conditions require customization and personalization to deliver 'what is best for me'.
- Filling the gaps – shoppers are looking for solutions to fill the nutrition gaps left by hurried lifestyles and eating habits (Gilbert, 2000).

Product development is leading to the arrival of enriched eggs on to the market place, which build on the basic qualities of the egg to meet changing lifestyle and life-stage consumer demands.

Prominent ethical views are often held about methods of production and associated decisions to purchase meat and eggs are set against a background of an increasing plethora of associated welfare assurances. However, opinions may be

misplaced when it comes to actually buying eggs, which is evident from the sales of cage-produced eggs and probably even more when the raw material is not so evident in the processed form. When one looks at the sales volumes of eggs from differing systems, it is apparent that consumers' views are not borne out by their purchasing behaviour. Elson (1991) suggests that there are two aspects of welfare: perceived welfare and real welfare. Perceived welfare is relatively easy for the consumer and supermarkets to decide, but welfare assessed on a scientific basis is much more difficult to determine. This makes any balanced promotional campaign to consumers on welfare issues very subjective.

Research undertaken by the Institute of Grocery Distribution (IGD, 2002) showed that an active interest in food production does not necessarily have an impact on purchase behaviour unless there is risk avoidance or personal benefit. This suggests that self-interest is at the centre of food choice for most consumers and that most decisions are based on self-benefit (e.g. value for money and taste) rather than being driven by altruistic motivations such as animal welfare and environmental issues.

Cost is seen to be the main inhibitor for market growth of products that meet the concerns for animal welfare (IGD, 2002). Consumers saw price as an important factor when buying eggs (Serati-Shirazi, 2003) and they also showed a firm opposition to buying foreign eggs, even if cheaper than UK Lion eggs. However, consumers do not buy on price alone, as price is part of perceived value, and value may mean many things to different buying segments. Value may equate to 'price + method of production + promotion + benefits + many other expectations' which may not always be overt or tangible. Current consumers of non-cage-produced eggs probably do place some value on animal welfare, as shown by the higher price they choose to pay for their eggs (although taste and quality may also influence their decision). There are fears that an increase in the domestic supply of non-cage-produced eggs will subsequently lead to a decrease in price for these eggs (DEFRA, 2002).

SURVEY OF CONSUMER ATTITUDES AND VIEWS

Summary of Findings

A survey was conducted by the author (Parrott, 2001) to evaluate the influence of quality assurance schemes on egg purchasing behaviour and to investigate the influence of method of production and packaging information on consumer purchases of eggs.

These objectives were undertaken through primary research in the form of a questionnaire distributed within the UK which sought to identify the current issues and attitudes of consumers to buying eggs and egg products and whether consumers' views were borne out by their purchasing behaviour. The questionnaire complemented an earlier survey undertaken in 1997 and was intended to measure consumer attitudes over time and provide information on current issues within the industry (Jones and Parrott, 1997).

Factors Influencing Consumer Choice and Attitudes Towards Egg Purchase

Eggs were seen to be a nutritious (mostly snack) meal, with many methods of serving, quick to cook, good value for money, reasonably cheap and part of a healthy diet. These views continue to endorse the theme 'Fast Food and Good for You' supported by the industry.

When the consumers in the survey were asked what they would consider to be the *two* most important factors they looked for when buying eggs, results showed that the type of egg production system the eggs came from, followed by date, assurance of freshness and price ranked the highest (see Fig. 2.1).

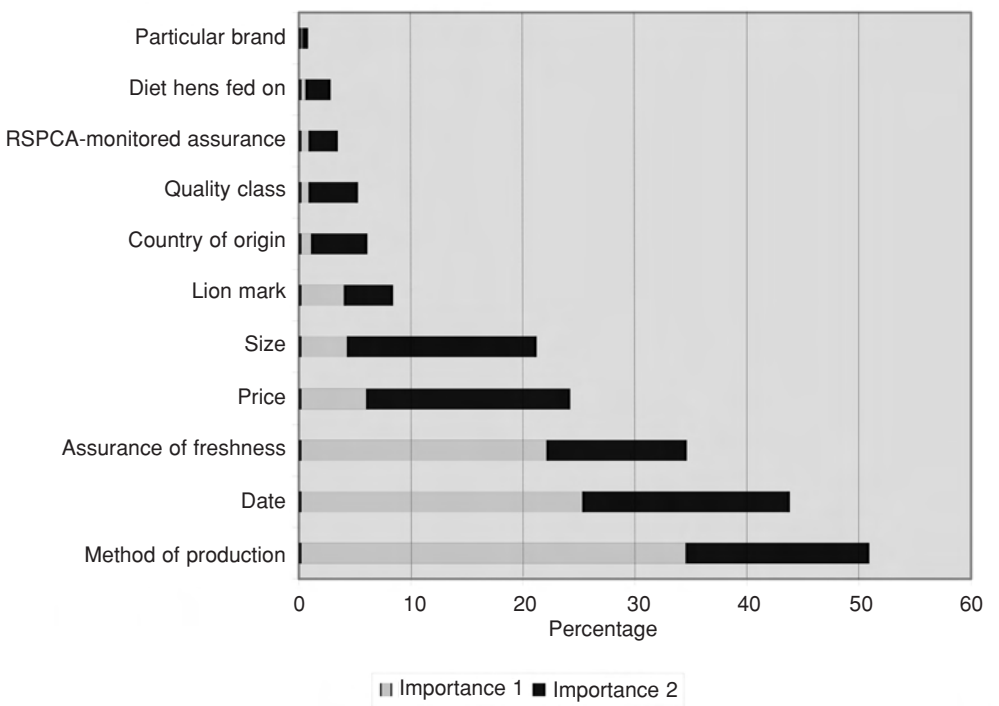

Fig. 2.1. The *two* most important factors considered by respondents when buying eggs.

A particular brand was apparently of limited interest to the respondents, but brand importance could be conveyed through the method of production, i.e. free-range or organic as a brand preference.

There was an element of consumers not acting on their beliefs when purchasing eggs, as shown by some of the answers to the survey. The questionnaire asked what factors the consumer considered when buying eggs and further questions followed to identify which particular information was checked on the label when buying eggs. These questions sought to match perceptions with purchasing behaviour. Results are presented in Table 2.1.

Despite concerns expressed about methods of production, the data in Table 2.1 show that only 24.3% of respondents said that they always looked for

Table 2.1. Consumer preferences and egg purchasing behaviour (data from Parrott, 2001).

Consumer base (n = 354)	Always %	Sometimes %	Never %
Look for reassurance on how the hen was looked after	24.3	15.0	60.7
Prefer to buy British	47.6	11.6	40.8
Prefer to buy eggs from your own region	10.5	16.6	72.9
Seek to buy eggs that have come from barn system	6.8	14.7	78.4
Seek to buy the cheapest eggs	12.7	15.5	71.7
Seek to buy organic eggs	11.0	13.0	76.0
Seek to buy eggs from a free-range system	41.3	21.0	37.7
Look to see what diet the hens were fed on	6.8	13.9	79.3
Like to buy eggs that are date-stamped on the shell	36.0	16.1	47.9

reassurance on how the hen had been treated. Less concern was shown by respondents who said they never looked to see what diet the hens had been fed on (79.3%), never sought out eggs from a barn system (78.4%), never bought organic eggs (76.0%), and never checked whether eggs came from their own region (72.9%), although 71.7% claimed not to buy the cheapest eggs.

With respect to buying British eggs, 47.6% said they always preferred to buy British, which compares with 40.8% who said they had no allegiance to buying British.

Recognizing the concern shown for the influence of method of production on their choice of eggs (as illustrated in Fig. 2.1), it was felt pertinent to ascertain each consumer's level of knowledge regarding each production system and to explore the views and knowledge of the respondents about the eggs from the different systems.

Ability to roam

Generally the level of understanding and knowledge of the industry on methods of production was poor. The survey showed that quite a large proportion of respondents had no idea about the extent to which hens are able to roam under each system and there was some confusion about the barn system.

Health and behaviour

It was largely believed that hens kept in caged systems would require more medication, as they would be more prone to disease and also more prone to fighting compared with other systems. However, 40% of the respondents said that they had no idea about differences in health and behaviour between systems.

Method of production and taste

The questionnaire sought to find out whether consumers believed that the taste of the egg was influenced by the different methods of production. A very small number (5%) believed that all eggs tasted the same and it did not matter what type of production systems the hens were in; however, over 50% of the respondents believed that there were differences in the taste of eggs. Over one-third (35%) of respondents believed that the *taste of the eggs appeared to be the main distinguishing feature* between free-range eggs and eggs from caged hens.

Very little opinion was expressed as to whether the different production systems had an effect on the nutritional value of the eggs or on the colour of the yolk. However, eggs with pale yellow yolks were believed to mainly come from caged hens and dark yellow yolks from non-caged production methods.

Concerns about the industry

The majority of concerns relating to the production of eggs in this country were to do with the production methods, with comments relating to 'intensive farming' and the 'sheer cruelty of battery cages'. However, despite their concern, 61% of the respondents said they had *never actually looked* for reassurance on how the hen had been looked after. Indeed very little awareness was shown as to whether British farmers had high standards of welfare. Generally, welfare concerns were expressed more strongly for the production of eggs than for poultry meat, and 40% of respondents said that they would pay more for eggs from a welfare-assured scheme. There were a few concerns about hormone and antibiotic use, but limited concern expressed regarding salmonella and cholesterol. The majority of consumers perceived that organically produced eggs would be more costly to produce than eggs produced by other systems. Two-thirds of the survey indicated that they would pay more for eggs not produced in cages, and when asked how much more they would be prepared to pay, this amounted to an average increase of 57 pence per dozen. Recent studies by Serati-Shirazi (2003) showed that consumers did make a positive distinction between enriched cages and conventional cages and suggested that this differentiation could be used as a key marketing aspect in sales and promotions.

CONCLUSIONS

There are many challenges facing the industry. The whole welfare issue is clouded by many contradictions, which include the buying patterns of egg consumers and customers, showing that they appreciate high-quality affordable products but mostly buy eggs from caged hens; the encouragement of producers to invest in alternative management systems when in reality the return on investment remains unpredictable and the benefit for the hens doubtful; and the possibility of a regional shift in welfare problems through the imposition of stricter welfare regulations in the EU.

There will be difficult battles ahead for producers to face with regard to the importation of egg products, as many of the imported eggs will be invisible through the growing processing/manufacturing sector, which is driven by price and function.

Whilst consumers have high ideals about the welfare of hens, there appears to be some level of over-claiming, as 80% of egg sales are from the produce of caged hens. While it is evident that some consumers will only consider the 'high-welfare' eggs regardless of price disadvantage, for other consumers, and despite much more clear labelling, there is still evidence of consumer confusion. Interest is likely to translate to behaviour if there is perceived risk avoidance or perceived personal benefit to the consumer. While the price of eggs is a major consideration for consumers (although they are reluctant to admit it), there is some indication that they are prepared to pay more for welfare-enhanced eggs. With the prediction of higher

levels of personal disposable income, alternative systems or innovations will benefit by becoming increasingly popular.

The industry should be proud of the investment it has made in the Lion scheme and efforts by all to minimize the risk of salmonella. In the first instance it establishes a simple defence message favouring home-produced eggs, incorporating safety, welfare and freshness. Consumer expectations are rising in respect of issues such as product quality, biosecurity, technical support, animal welfare and food safety, which are of paramount importance throughout the food supply chain. Perceptions are difficult to build and easy to destroy regardless of the facts. It has taken a great deal of effort and investment by the egg industry to achieve this trust through the Lion scheme and other assurance schemes, and yet it could all be lost so easily through errors of judgement on buying practices.

With changing lifestyles, consumer demand is shifting to more meals eaten out of the home and a snacking and grazing society. It is important that the industry stays abreast of this growth and ensures that eggs play an important role in the diet. If one had to design a food product for a growth market, eggs have it all. Eggs have good nutrient quality, are tasty and versatile, have convenient portion control, form part of a healthy diet and are fast and easy to prepare. In addition they offer great potential as a promotional partner. In essence, eggs need repositioning in the consumer market and, with improved merchandizing, specific product messages, interest in functional foods and refined segmentation to suit all lifestyles and life stages, there are still exciting challenges ahead for the industry.

REFERENCES

Aaker, D.A. (1996) *Building Strong Brands: Brand Equity*. Free Press, New York.

BEIC (British Egg Industry Council) (2001) http://www.britegg.co.uk/BEIS/BEIS4.html (accessed 25-08-01).

BEIC (British Egg Industry Council) (2002a) *The UK Egg Industry: Internal Costs and Trade Liberalisation*. British Egg Industry Council, London.

BEIC (2002b) http://www.britegg.co.uk/beissection/beis_markdt.html (accessed 03/07/03).

BEIS (British Egg Information Service) (2002) http://www.britegg.co.uk/advertsection/press17.html (accessed 03/07/03).

De Chernatony, L. and McDonald, M. (1992) *Creating Powerful Brands*. Butterworth/Heinemann, Oxford.

DEFRA (Department for Environment, Food and Rural Affairs) (2002) *Proposed Amendment. Partial Regulatory Impact Assessment, July 2002*. DEFRA, London.

Elson, A. (1991) *Attitudes to Poultry Welfare: Proceedings of Conference held on 26 February 1991*. BVA Animal Welfare Foundation, London.

Fearne, A. and Lavelle, D. (1996) Segmenting the UK egg market: results of a survey of consumer attitudes and perceptions. *British Food Journal* 98, 7–12.

Gilbert, L. (2000) What's next and what the Americans think about eggs. *Presented to the International Egg Commission September 2000*. Health Focus, Des Moines, Iowa.

Heil, G. and Flock, D.K. (2002) Conflicting perceptions of cages. Letter to Editor, *World's Poultry Science Journal* 58 (Sept), 388.

IGD (Institute of Grocery Distribution) (2002) *Expanding Consumer Choice*. IGD, Watford, UK.

Jones, W. and Parrott, P. (1997) *Consumer Perceptions of the Poultry Industry*. Report No.6 Temperton Fellowship, Harper Adams University College, Newport, UK.

Kotler, P. (2003) *Marketing Management*, 11th edn. Prentice Hall, London.

Mintel (2002) *Eggs: Market Intelligence*. Mintel International, London.

Parrott, P. (2001) *Eggs: Consumer Buying Behaviour*. Discussion Paper, Harper Adams University College, Newport, UK.

Poultry World (2001) September UK facts and forecasts. *Poultry World* Sept 2001, 26.

RSPCA (2001) *Hardboiled Reality: Animal Welfare-Friendly Egg Production in a Global Market*. Royal Society for the Prevention of Cruelty to Animals/ Eurogroup for Animal Welfare, Horsham, West Sussex, UK/ Brussels.

RSPCA (2002) *Uncaged Egg Survey: Animal Welfare Report*. Royal Society for the Prevention of Cruelty to Animals, Horsham, West Sussex, UK.

Serati-Shirazi, O. (2003) *An investigation into enriched cage production as a suitable substitute for conventional laying cages*. Thesis submitted in partial fulfilment of the requirements of the BSc (Hons) Degree in Agri-food Marketing with Business Studies. Harper Adams University College, Newport, UK.

Southgate, P. (1994) *Total Branding by Design: How to Make your Brand's Packaging More Effective.* Kogan Page, London.

van Horne, P.L.M. and Bondt, N. (2003) *Impact of EU Council Directive 99/74/EC: Welfare of Laying Hens on the Competitiveness of the EU Egg Industry*. LEI, The Hague.

Wolfram, R., Simons, J., Giebel, A. and Bongaerts, R. (2002) Impacts of stricter legal standards in the EU for keeping laying hens in battery cages. *World's Poultry Science Journal* 58 (Sept).

CHAPTER 3
Government views on the welfare of laying hens

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INTRODUCTION

In the UK the Government has been involved in developing welfare legislation for over 200 years. More recently it has played a major part in the development of legislation at a European level, both as a member of the European Union and of the Council of Europe Conventions on Animal Welfare. The definition of animal welfare involves both ethical and scientific considerations and there are many conflicting views on how animal welfare should be defined. The role of government in animal welfare extends beyond the preparation and enforcement of legislation. Improved standards of animal welfare are important for society, the economy and the environment *per se* and are an integral part of sustainable development. As welfare policies and enforcement activities are firmly based on science and practical experience, the Department for Environment, Food and Rural Affairs (DEFRA) also funds research and surveillance activities. The development of animal welfare policy involves understanding the relevant scientific evidence and practical experience and must take account of the wide range of views held by the various stakeholders. Recent progress in farm animal legislation has provided not only protection from cruelty and suffering but also introduced a duty of care on keepers to take steps to protect their welfare. A review of UK legislation on welfare is currently under way to extend such standards to all animals kept by man. Future government policy is to ensure sustainable development, and a new animal health and welfare strategy is being developed. The UK recognizes the need for international standards as a basis for bilateral/multilateral agreements and supports the work of the OIE (Organisation Mondiale de la Santé Animale – World Organisation for Animal Health) in this respect. There is a need to ensure that high welfare standards are achieved without jeopardizing efforts to assist developing countries to reduce poverty through trade.

SUSTAINABLE DEVELOPMENT

DEFRA has broad and challenging policy responsibilities that directly impact upon people's quality of life. That is why sustainable development is the overarching aim

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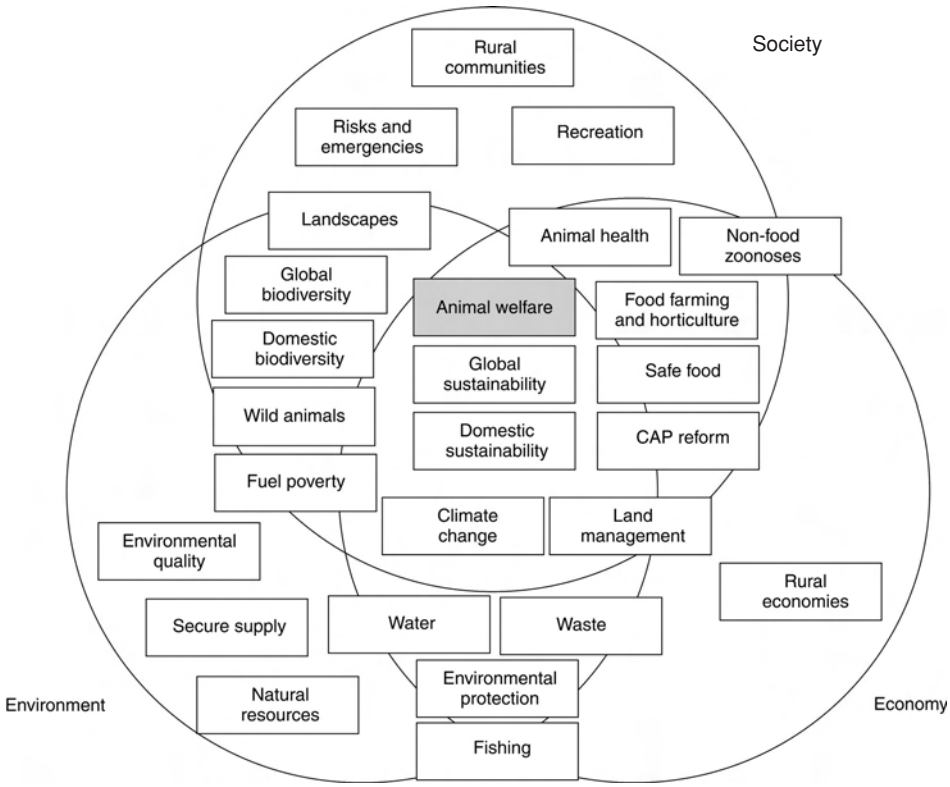

Fig. 3.1. DEFRA's spheres of influence.

of the department, as well as being vitally important for the Government as a whole (DEFRA, 2002a).

A widely used international definition of sustainability is 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs'. The commitment to 'ensure a better quality of life for everyone, now and for future generations to come' is at the heart of the UK Sustainable Development Strategy. This is a simple idea but a substantial task. Improved animal health and welfare is but one of many outcomes at which this strategy is aimed. DEFRA has a wide sphere of influence which is summarized in Fig. 3.1.

The creation of DEFRA brought together government responsibility for most animal policies. The UK Government launched its Strategy for Sustainable Farming and Food in December 2002, which encompasses animal health and welfare, including:

- High standards vital to achieve sustainable and humane livestock production, and industries that produce safe, good quality food.

IMPROVING WELFARE STANDARDS

One of the main high-level objectives of DEFRA (Objective VI) is to:

> Protect the public's interest in relation to environmental impacts and health and ensure high standards of animal health and welfare.

It does this through a range of activities from international negotiation on welfare standards and rules in the Council of Europe (CoE), the European Community (EC) and other forums, to providing practical advice to the livestock industries and, of course, the implementation and enforcement of legislation and welfare codes.

There are widely ranging perceptions of what constitutes good or bad welfare and the role of government is to set welfare standards which can be adjusted in the light of new scientific knowledge and changing societal perceptions of what is or is not acceptable treatment of animals. There is therefore a need to liaise with a wide range of stakeholders and others. Figure 3.2 summarizes the major inputs involved in the development of animal welfare policy.

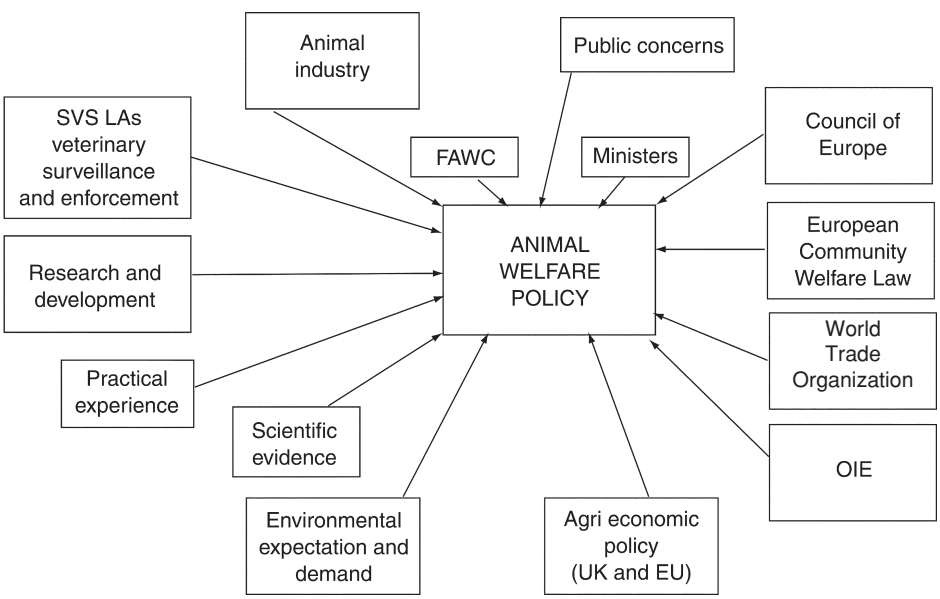

Fig. 3.2. Major inputs of DEFRA Animal Welfare policy.

RESEARCH AND DEVELOPMENT

As welfare policies and enforcement activities are firmly based on science and practical experience, DEFRA also funds research and surveillance activities. The welfare research programme covers the full range of farmed livestock.

The overall objectives of the research programme are to:

- Resolve uncertainties as to the exact nature of welfare requirements and

to identify ways in which these requirements can be met under commercial conditions: projects involving collaboration between research providers and industry are encouraged in order to provide scientific data to help ensure that decisions are not taken on the basis of subjective or emotional considerations.

- Poultry – laying hen bone strength, feather pecking and aggressive behaviour, and the design of enriched cages and epidemiological studies on welfare of poultry systems.
- Transport – effect of vehicle design and heat stress, non-invasive methods of physiological monitoring.
- Slaughter – improvement in existing techniques and development of novel methods of slaughter, such as gaseous stunning and killing.

WELFARE CODES

In the UK much effort has been expended to ensure that livestock keepers are aware of the legislation by the development of statutory codes for welfare which now include the relevant legislation, e.g. the Laying Hen Code (DEFRA, 2002b). This new code implements most of the recommendations made in the Farm Animal Welfare Council's report on *The Welfare of Laying Hens in Colony Systems* (FAWC, 1991). It also takes account of new developments in both science and practical experience, including some of the recommendations of the EU Scientific Committee on Animal Health and Animal Welfare's report on *The Welfare of Laying Hens* (Anon., 1996a). It also includes the recommendations of the Council of Europe on domestic fowls (Anon., 1996b). Wherever possible, the results of research and development are incorporated into advisory leaflets, which are sent to livestock keepers. Welfare publicity campaigns also include outcomes of research and are targeted at specific farmers and their veterinarians. The recent codes envisage an important role for the veterinary profession in improving standards of welfare on laying hen farms. As well as the established roles of providing expert advice, veterinary surgeons would also play a role in providing general welfare advice, biosecurity advice and perhaps training, especially in the development of particular skills by stockmen related to routine medical procedures. Welfare codes now require a health and welfare plan prepared with veterinary advice. This plan should set out biosecurity measures, health and husbandry activities that cover the whole year's cycle of production, and should include strategies to treat or limit existing disease problems. The plan should include enough records to assess the basic output of the flock. Among the lessons learned from the 2001 outbreak of foot-and-mouth disease (FMD) was the need to improve and maintain high standards of biosecurity. Recent outbreaks of avian influenza in Europe remind us of the threats of exotic disease to the poultry industry, but biosecurity is also important to prevent the spread of endemic diseases which can adversely affect the welfare of hens.

ENFORCEMENT

The State Veterinary Service (SVS) operates throughout Great Britain as a unified service within the Operations and Service Delivery Directorate General of DEFRA.

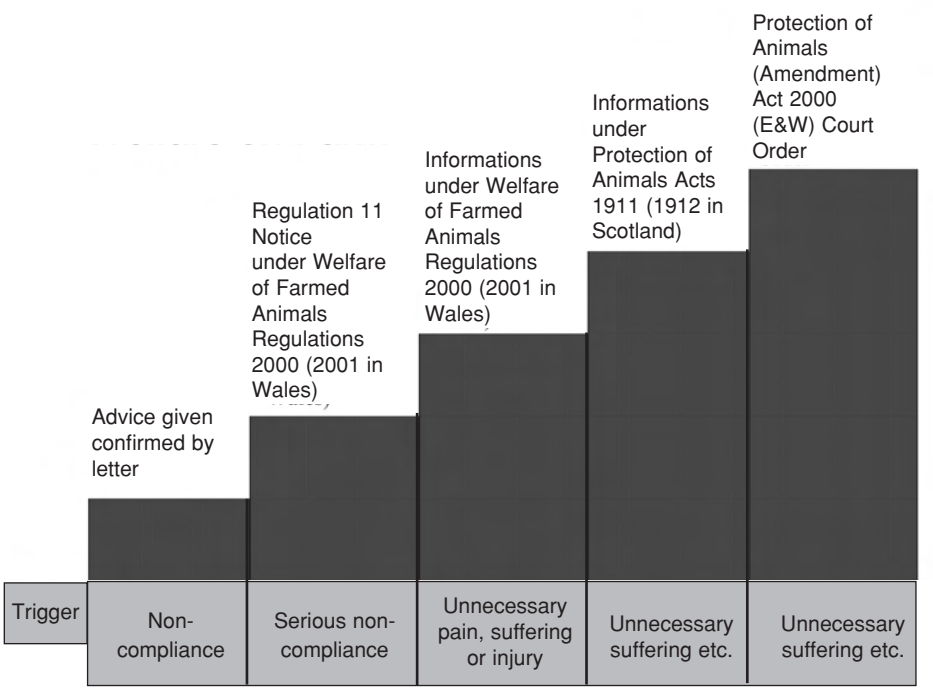

Fig. 3.3. Dealing with incidents concerning poor welfare on farms.

Its role is to assist DEFRA and other government departments in achieving their aims in the fields of animal health, public health, animal welfare and international trade. In addition to spot-checks and planned visits, the SVS follows up all complaints and allegations of poor welfare from the general public and others on specific farms as a matter of urgency.

Although most animal keepers are keen to cooperate when inspection reveals poor welfare, these powers are useful for ensuring full compliance with the regulations and thereby improving livestock welfare. There are a variety of measures which can be taken to ensure compliance with the legislation. These are summarized in Fig. 3.3. These vary from providing advice to the serving of a notice, usually by a veterinary inspector under Regulation 11 of the Welfare of Farmed Animals Regulations 2000 (2001 in Wales) (WoFAR). Such notices can require the keeper to take action to protect the welfare of the animals. This has varied from providing a suitable diet in sufficient quantity, to a requirement to seek veterinary advice and take action to implement that advice.

The next step is for the lay informant to start prosecution proceedings either under WoFAR or the Protection of Animals Acts. There is provision under the Protection of Animals Act for the destruction of animals, following consultation with a police officer. New powers in the Protection of Animals (Amendments) Act (2000) gave powers to the court to permit the authorized prosecutor to take action to protect the animals subject to the information supplied. This could include caring for the animals *in situ* or seizing, selling or

slaughtering the animals. The Act also contains safeguards to protect the interests of the keeper.

There has been considerable interest recently in enriched cages and beak trimming of laying hens.

ENRICHED CAGES

DEFRA carried out a public consultation exercise on whether to ban enriched cages for laying hens in England at the same time as conventional barren cages are due to be banned in 2012. Elliot Morley announced the UK Government's position on 18 March 2003 (see http://www.defra.gov.uk/news/2003/030318a.htm).

After a thorough consideration of the comments received and the available scientific and other evidence, Ministers concluded that, as there is a lack of definitive evidence currently available, there are insufficient grounds at present to justify a unilateral ban on enriched cages from 2012.

Because there are many issues to consider, a better approach would be to review the future of enriched cages on an EU basis, when the Welfare of Laying Hens Directive is next considered by the Agriculture Council in 2005. By then it is hoped we will be in a stronger position to address some of the questions on the welfare concerns of enriched cages, as research programmes are completed.

BEAK TRIMMING

In order to prevent feather pecking and cannibalism, until 31 December 2010 beak trimming of birds is permitted in all systems subject to requirements set out in Schedule 3D, paragraphs 8 and 9 of the Welfare of Farmed Animals (England) (Amendment) Regulations 2002 (SI 2002 No. 1646). Representatives from the industry and welfare groups have joined DEFRA to work on an action plan to enable a ban on beak trimming to take place without compromising bird welfare.

- The group will review research into the causes of feather pecking and management controls to disseminate recommendations to the industry.
- ADAS have begun a pilot study to look at alternatives to beak trimming. These will include using an abrasive material in the food troughs to blunt the sharp point of the beak as the hen feeds.
- The British Egg Industry Council will coordinate a code of practice for beak trimming. This will look at methods and training for beak trimming to provide advice on best practice when the procedure is carried out.
- Breeding companies are continuing work on breeding programmes to prevent feather pecking and cannibalism.

ANIMAL HEALTH AND WELFARE STRATEGY

The future policy on the welfare of laying hens will be an integral part of the Government's strategy for animal health and welfare, as recommended by the

Policy Commission report on *The Future of Farming and Food* and the recent FMD inquiries. The Animal Health and Welfare Strategy is being developed in partnership with the Scottish Executive and the National Assembly for Wales, with links to the Northern Ireland 'Island of Ireland' programme.

The strategy will provide a comprehensive view of all our commitments to animal health and welfare. It will provide a framework to assess the threats of animal diseases and prioritize actions. The role of research and science in animal health and welfare will be developed and there will be an opportunity to look at current best practice and to learn from international experiences.

The aim is to issue an interim Strategy and outline delivery plan in the summer of 2003, with publication of the Strategy due later in the year.

REFERENCES

Anon. (1996a) *The Welfare of Laying Hens*. Scientific Committee on Animal Health and Welfare, European Commission, Brussels.

Anon. (1996b) *Recommendations Concerning Domestic Fowl (*Gallus gallus*)*. European Convention on the Protection of Animals Kept for Farming Purposes. European Treaty Series, No 87. Council of Europe, Strasbourg.

DEFRA (2002a) *Foundations for our Future: DEFRA's Sustainable Development Strategy* (http://www.defra.gov.uk/corporate/sdstrategy/sdstrategy.pdf). PB 7175, Department for Environment, Food and Rural Affairs, London.

DEFRA (2002b) *Code of Recommendations for the Welfare of Livestock: Laying Hens*. PB 7274, Department for Environment, Food and Rural Affairs, London.

FAWC (1991) *Farm Animal Welfare Council's Report on the Welfare of Laying Hens in Colony Systems.* PB 0734, Ministry of Agriculture, Fisheries and Food, Tolworth, UK.

CHAPTER 4
The politics of hen welfare

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ABSTRACT

Animal welfare organizations throughout Europe have been concerned for many years about the welfare of hens in battery cages. Reasons for this concern include the lack of space, the inability of the hens to perform several natural behaviours, and the barren environment.

It has been obvious for some time that the only way to improve the welfare of laying hens was through European legislation. Governments in the member States of the European Union (EU) were unwilling to introduce legislation on this production method.

European Directive 88/166/EEC had done nothing to improve the welfare of hens but only laid down minimum standards which included a space allowance of 450 cm^2/bird. The Directive contained an article which required the Commission (by January 1993) to report on the scientific developments regarding the welfare of hens under various systems of rearing, accompanied by appropriate legislative proposals.

The first report of the Scientific Veterinary Committee (SVC) in 1992 was never published and it was not until a second SVC report was prepared in 1996 and then published that the Commission took action.

The Commission was committed to preparing a new Directive on minimum standards for the protection of laying hens in all production systems. The proposals were published in 1998. They did not include a ban on the battery cage but advocated more space per bird, more height to the cages etc.

The proposed new Directive did not please animal welfare organizations and was rejected by the European egg industry. Nevertheless, it was submitted to the European Parliament for an opinion and the Council formed working groups to debate a compromise.

All legislation ultimately requires a 'political' decision. In the EU this decision had to be taken by a qualified majority of the 16 Ministers in the Agriculture Council.

The politics could seen as a description of the 'battle' that took place between governments, the European Parliament, the industry, and animal welfare organizations led by the Eurogroup for Animal Welfare. This 'battle' lasted from the date of publication of the Commission's proposal until the eventual decision of the Council of Ministers on 19 July 1999. A summary of the main elements of that 'battle' will be given and also a look into the future.

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INTRODUCTION

Eurogroup for Animal Welfare

Eurogroup for Animal Welfare represents the 15 leading animal welfare organizations in the European Union. Its purpose is to present a united voice on animal welfare in the EU institutions and to achieve greater animal welfare through new or improved European legislation.

Background to Legislation

Animal welfare organizations throughout Europe have been concerned for many years about the welfare of hens in battery cages. Reasons for this concern included the lack of space, the hens' inability to perform several natural behaviours, and the barren environment.

It had been obvious for some time that the only way to improve the welfare of laying hens was through European legislation. Governments in the member States of the European Union (EU) were unwilling to introduce national legislation on this production method, as they could have been putting their own producers at a commercial disadvantage.

The stimulus for the first attempt to legislate on battery cages came from a German high-court decision. The court ruled that keeping hens in battery cages contravened German animal welfare legislation. However, the court conceded that, as virtually all egg production at that time was from the battery-cage system, no penalty would be applied to the farmer who had been prosecuted. Instead the German government was advised to go to Brussels and resolve the problem. This resulted in a proposal from the Commission to set standards for hens in battery cages. No real attempt was made to consider the welfare of the laying hens. It was more a means to 'legitimize' the existing commercial practices. This was agreed in Council in 1986 – as Directive 86/113/EEC. The animal welfare movement referred to it as the Directive which laid down standards for the protection of egg producers.

A peculiar sequel was that the UK and some other member States argued that the 1986 Directive, *as published*, differed in some of the wording to that agreed by the Council of Ministers in March 1986. The Court of Justice in Luxembourg eventually upheld the complaint. Minor changes to the wording were made and the Directive was republished in 1988.

DIRECTIVE 88/166/EEC

European Directive 88/166/EEC had done nothing to improve the welfare of hens but only laid down minimum standards which included a space allowance of 450 cm^2 per bird. The other main provisions are as follows:

- A feed trough length of at least 10 cm/hen.
- A continuous drinking channel of at least 10 cm/hen or two nipple drinkers or drinking cups in each battery cage.

- A height of at least 40 cm over 65% of the cage area and not less than 35 cm at any point.
- Floor slope not to exceed 14% or 8°.

All these provisions had to apply to all battery cages from 1 January 1995.

In the Annex to this Directive, there appeared several provisions including the following:

- The design and size of the cage opening must allow an adult hen to be removed without injury.
- Birds to be inspected at least once a day and, if necessary, thoroughly inspected.
- More than three tiers permitted only if inspection can be carried out without difficulty.
- Stockmen required to have adequate knowledge and experience.

Very importantly, the Directive also contained an article which required the Commission (by 15 January 1993) to report on the scientific developments regarding the welfare of hens under various systems of rearing, accompanied by appropriate legislative proposals. A formal revision of the Directive would provide an opportunity for amendments to be introduced and to make real welfare progress.

One important consequence of the legal challenge to this Directive was that in the hearing in the Court of Justice in Luxembourg, and as part of the Court's opinion, it was confirmed that under the Common Agricultural Policy it was legitimate for the Community to establish minimum standards for rearing farm animals in order to avoid unfair competition. This was a vital decision for animal welfare and Eurogroup, because some member States were challenging the legal basis under which the Commission could make proposals to improve the welfare of farm animals.

SCIENTIFIC REPORT

In accordance with the Directive's timetable, a report was prepared by the Scientific Veterinary Committee (SVC) in 1992. This was very critical of the battery-cage system, but it was never published and the Commission did not act on it. A more welfare-sympathetic Commissioner – Franz Fischler – became responsible for agriculture in 1995. He asked for another SVC report, which was published in 1996.

The Scientific Report's conclusions were again critical of the battery cages and included a statement that said that there were 'inherent severe disadvantages for the welfare of hens …'. The other main conclusions were as follows:

- Hens have a strong preference for laying eggs in a nest, for pecking and scratching at litter and for dust-bathing.
- Hens have a preference to perch and perches contribute to greater bone strength.
- Sufficient light should be provided to allow natural behaviour to be performed.
- Alternative production systems do carry a risk of feather pecking and cannibalism.
- Production costs are higher for non-battery-cage systems and, therefore, EU producers may need to be protected from imports from non-EU countries with lower welfare standards.

This time, the Commission was committed to preparing a new Directive on minimum standards for all production systems. The proposals were published in 1998. They did not include a ban on the battery cage but advocated more space per bird, more height to the cages etc.

LEGISLATIVE PROCESS

The proposed new Directive did not please animal welfare organizations and was rejected by the European egg industry. Nevertheless, it was submitted to the European Parliament and the Economic and Social Committee (ESC) for an opinion and the Council formed working groups to discuss the technical aspects of the proposal.

All legislation requires a 'political' decision. In the EU this decision had to be taken by a qualified majority of the 15 Ministers in the Agriculture Council.

There are several definitions of 'politics' in the dictionary. One of the more interesting is 'the practice of the art and science of forming, directing and administering states and other political units'.

Thus, all the people involved in such activities can be described as politicians, although we tend to reserve that term for elected Members of Parliaments. It could also be argued that all lobbyists could be described as politicians, particularly if one considers another dictionary definition: 'any activity concerned with the acquisition of power and gaining one's own ends'.

As far as Eurogroup was concerned, 'gaining our own ends' seemed a long way off at the time the proposed new Directive was published. What then followed was a fascinating political 'battle' between the Council of Ministers, the European Parliament, the Commission, the industry, animal welfare organizations led by Eurogroup, and the public.

One thing clear at the beginning of this 'battle' was that very few people from any of the stakeholders believed that the battery-cage system would be phased out. The main reasons for this pessimism included the following:

- The system provided over 90% of all eggs produced in the European Union.
- There were welfare problems with some of the commercial alternative systems.
- There was a question mark over whether or not consumers were prepared to pay more for 'welfare-friendly' eggs and egg products.

How the proposed end to the battery cage came about is a fascinating story. It is believed that the main reasons for this animal welfare success are as follows:

- The SVC criticism of the battery cage system was strong, particularly in the use of the word 'inherent'.
- The egg industry was complacent about its political influence and dismissive of the welfare arguments.
- The Commission and several member States were not opposed to the principle of getting rid of the battery-cage system.
- The influence of the Parliament, even in a consultation procedure, was greater than most people believed.
- The lobbying carried out by Eurogroup for Animal Welfare was successful.

The SVC report was strongly critical of the battery cage, but at the same time it also criticized some aspects of the alternative systems. However, the overall scientific conclusion had to be that the welfare of the hen was much better served in one of the alternative systems. There was a reference to enriched cages in the SVC report, but as a consequence of a lack of scientific evidence and practical experience, no firm recommendations were made. Nevertheless, the new 1999 Directive did allow for enriched cages and laid down conditions.

What many people either ignore or forget is that whilst good animal science is essential for animal welfare progress, advances may also occur as a result of a variety of other factors: public concern, market forces, political pressure, practical experience and plain old-fashioned common sense.

Egg Industry

The egg industry's attitude was interesting in so far as it dismissed the Commission's proposal as unreasonable, impractical and unwanted. There was no attempt at any constructive debate or comment. Within the Commission Committee structure there is a Poultry and Eggs Management Committee. A statement issued by the joint chairmen of that committee shortly after the draft Directive was published is a reflection of the industry's arrogance.

Political Support/Public Pressure

It does not need much imagination to realize that if the public is shown an image of an animal in cage – particularly with very little room to move – then the reaction against such an image is immediate and, with good campaigning, long lasting.

Public opinion, if organized, means pressure on governments. Eurogroup's member organizations were well prepared to launch campaigns in all member States with the intention of bringing pressure to bear on Ministers to outlaw the battery-cage system. Some of these campaigns were successful in influencing the decisions taken by some governments, particularly in Italy.

It was clear to Eurogroup from many discussions with officials in the Commission – DG Agriculture at that time – that there was support for the phasing out of battery cages, but that it was believed to be difficult from an economic point of view and would not receive political support. Nevertheless, support for alternative non-battery systems was strong in Sweden, Denmark, The Netherlands, the UK and Germany.

European Parliament

Eurogroup believed that the opinion of the European Parliament might well be of critical importance. The rapporteur in the Agriculture Committee was a German socialist, also a veterinarian, who was sympathetic to the Eurogroup point of view, but who felt that a proposal to phase out the battery-cage system would not be supported by his Committee. He proposed several improvements to the Commission's text, which the Committee supported, but his judgement was

correct and the proposal to prohibit cages was rejected. Then came the vote on that report in the Plenary. This was a different scenario. Three amendments to phase out the battery cages were submitted. One came from the right-wing People's Party of Europe (PPE) (formerly the Christian Democrats), one from the Socialists and one from the Greens. In the event it was the PPE amendment that was successful. Sponsored by an Italian member of the European Parliament, it called for the phasing out of the battery cage by 2009. It was passed by a large majority and of particular significance was that a large number of Italian MEPs from all political groups supported it. This did not go unnoticed in Rome.

Almost immediately after this vote there was a dramatic shift in the nature of the discussion at Council level. For the first time the phasing out of the battery cage was seriously discussed and the date of 2012 was eventually agreed. The battle was over on 19 July 1999.

DIRECTIVE 1999/74/EC

As with all legislation which lays down radical changes, there has to be a phasing-in period. There is a series of dates in the 1999 Directive which are as follows:

- From 1 January 2002: enriched cages must provide 750 cm^2 space/hen plus a nest, perching space of 15 cm/hen and litter.
- From 1 January 2002: all new alternative systems – maximum of 9 hens/m^2.
- From 1 January 2003: conventional cages to provide at least 550 cm^2 of space/hen – no new cages to be introduced.
- From 1 January 2007: all alternative systems – maximum of 9 hens/m^2.
- From 1 January 2012: conventional cages will be prohibited.

Although this was a great success for animal welfare, many feel that a counter-attack is still possible. There are those in the industry who believe that this Directive can be overturned when it is subject to a review by 1 January 2005. Speaking from the Eurogroup perspective, such a move would be politically unacceptable.

Another concern, one which is entirely reasonable, is how does the EU cope with competition from non-EU countries which can offer a cheaper product because of the extra costs borne by EU producers. Eurogroup are working with the industry on that problem (see Chapter 5).

Enriched Cages

The subject of enriched cages remains. This is the system which will save the EU egg industry, or so some people claim. Surprisingly, most of the research on modern enriched cages has been carried out in Sweden – an animal-welfare-conscious country. I have seen several examples of the enriched cage and I have not been impressed. Furthermore, I was taken aback when I visited Gleadthorpe Experimental Husbandry Farm in March 2003 to find that the majority of the research on enriched cages involved studying the effects of space allowances less than the 750 cm^2 required under the 1999 Directive and with a height also less than that specified in the Directive. You have to ask why. Presumably because the Government will seek changes to the Directive when it is reviewed.

Let me make one thing very clear. We in Eurogroup, and I think I can speak on behalf of the whole animal welfare movement in Europe, are opposed to hens in cages. I am not convinced that the provisions for a nesting area and perches in enriched cages are as good for hen welfare as some people claim. In some systems the nest is not used by all the birds, with up to 20% of eggs laid outside the nest and the amount of perch space and the design of the perches also appears to be inadequate. Also, in many examples, the requirement for litter for pecking and scratching is simply ignored.

It follows, therefore, that not only will Eurogroup resist any attempt to downgrade the conditions laid down in the Directive, but if the legislative debate is reopened, then we may well seek to get enriched cages prohibited completely.

Egg Labelling

Finally I must refer to another new Commission regulation, which is to make obligatory the labelling of eggs according to the method of production. There are three categories – cage eggs, barn eggs and free-range eggs. When this finally came into force on 1 January 2004 all European consumers were properly informed for the first time and, in my opinion, the sales of non-cage eggs will increase. However, we would also wish to see such labels placed on all imported eggs.

The politics of hen welfare – at least as far as egg-layers are concerned – has gone quiet for the moment. Eurogroup believes that the present legislation will eventually improve the welfare of laying hens and we will continue to try to ensure that these improvements are maintained.

CHAPTER 5
Impact of the World Trade Organization on hen welfare

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ABSTRACT

The relationship between the multilateral trading system and national measures to improve non-trade concerns, such as animal welfare, is becoming increasingly important. The egg industry in the European Union provides the first real test case of how this relationship will impact on the competitiveness of a farming industry. This was foreseen in the negotiations that led up to the adoption of Directive 1999/74/EC. The review of that Directive coincides with the conclusion of the agricultural negotiations under the Doha Development Round at the end of 2004.

This chapter examines the relationship between the General Agreement on Trades and Tariffs (GATT) and animal welfare and the discussions under the WTO (World Trade Organization) Agreement on Agriculture (AoA).

INTRODUCTION

When the multilateral trading system was set up in 1948, there was little, if any, thought about the consequences of these rules on issues such as the environment or farm animal welfare standards. The first attempt to discuss such issues occurred in 1972 when GATT set up a contact group on the environment, which never actually met until environmental issues were first raised at the GATT in the early 1990s. Discussion on environmental issues assumed more importance in the 1990s, particularly over issues raised by the two dolphin–tuna cases (Anon., 1991, 1994). Non-trade concerns were acknowledged in the first rules that were set up on agricultural trade at the conclusion of the Uruguay Round in 1994 (WTO, 1994). Animal welfare was first proposed as a non-trade concern by the European Commission in its submission to the agricultural negotiations in 1999. Negotiations are proceeding on the best way to incorporate a solution to the issues raised under the agricultural agreement.

The laying hen industry in the European Union provides the first real test case of how the relationship between free-trade rules and animal welfare standards will impact on the competitiveness of a farming industry. This was foreseen in the negotiations that led up to the adoption of EU Directive 1999/74/EC, which sets the European standards for laying hens (EC, 1999). A review of Directive 1999/74/EC is required in order to assess the systems of laying hen management

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and examine the socio-economic implications of the various systems and their effects on the Community's economic partners. The review date of 1 January 2005 coincides with the deadline imposed on the agricultural negotiations currently taking place under the Doha Development Round. In addition, the EU's egg-labelling scheme changed on 1 January 2004 to one requiring mandatory labelling showing the method of production or, in the case of imported eggs, the country of origin. This also has implications for the WTO's rules on labelling under the Technical Barriers to Trade Agreement (TBTA).

There are two important elements that need to be analysed if an accurate assessment is to be made of the effect of the WTO's impact on the European hen industry. The first of these is the rules and framework of the WTO and their effects on measures to raise and maintain high animal welfare standards. The second is the economic competitiveness of the egg industry and the consequences of raising welfare standards.

RELATIONSHIP BETWEEN GATT AND ANIMAL WELFARE

The framework of the GATT '47' rules, which are incorporated into the World Trade Organization, are based on the premise that one contracting country should not discriminate against another. Articles I, III and XI are the most relevant from a farming perspective. Article I requires that any WTO member does not give a trade advantage or any other favour or immunity unless it is granted to all parties. Article III states that 'like products' from external sources should be treated the same way as domestically produced ones. Finally, Article XI limits the power of member countries to ban the imports of products unilaterally.

The first tuna–dolphin case in 1991, although unadopted, found that the USA, by imposing import bans on certain tuna due to the methods by which they were caught, was in contravention of its obligations under the GATT rules. Although the ban was imposed to protect dolphins which were being caught by certain methods of tuna fishing, it was ruled to be incompatible with the GATT rules. The ruling stated that the measure discriminated against 'like' products. The method of tuna fishing did not alter the product, defining a product distinction as one based on a physical difference in the product. This point is particularly important to animal welfare measures as it has been interpreted to mean that distinctions cannot be made between products based on their method of production. An egg from an intensive farming system in the USA should be treated no differently than a free-range egg produced in the UK. As improvements in animal welfare measures rarely result in a physical change in the end product, this ruling could be seen as a watershed in defining what trade methods could be applied to ensure that high welfare standards can be maintained in a global trade environment. However, crucially, this decision was never adopted. Although the interpretation has never been subsequently challenged, it could be possible for a different interpretation to be made by another panel.

Article XX does allow exemptions to these rules, specifically if the measures are necessary to protect public morals or animal life or health. There are several tests that the trade measure would have to pass if it was to be allowed under these exemptions. Firstly, it would have to be defined as a measure to protect public morals or animal life. Secondly, it would have to pass further tests under the

chapeau of Article XX, namely that the measure is not arbitrary, unjustified or a disguised restriction on trade. To assess how these exceptions have been interpreted, it is necessary to look at the dispute mechanism under the WTO.

If a dispute arises and a member takes out a challenge against another member's legislation, decisions are made under the Dispute Settlement Understanding, which dates from the Uruguay Round. Decisions are reached by a panel of trade experts. The changes introduced in 1995 have introduced two important issues to the system: the process is now quicker than it was prior to the Uruguay Round and any decisions are binding once completed. To date there have been no disputes on animal welfare issues, so we have to look to environmental challenges for jurisprudence.

There have been eight challenges to environmental or human health measures where panels have examined the appropriateness of the measures under the Article XX exceptions, four under the Dispute Settlement Understanding. There are a number of lessons to be learnt from these disputes. In general terms, it is up to the party invoking Article XX (invariably the one defending the case) to prove that the measure meets the criteria for the exceptions. Secondly, the provisions under Article XX have been interpreted narrowly to date. Finally, the panel rulings have pointed out that the crucial issue is how the measure is implemented, and in particular whether there has been an attempt at solving the problem through a multilateral channel.

The panel rulings also show how difficult it is to mount a successful defence under the Article XX exemptions. Several panels have agreed that the disputes qualify under the definitions in Article XX. The measures under both the shrimp–turtle dispute (WTO, 1998) and the gasoline case (WTO, 1996) passed the exceptions test under Article XX(g), with the panel acknowledging that turtles and air, respectively, are an exhaustible natural resource. However, both measures failed the Article XX chapeau test, as they were found to be disguised restrictions on trade and were an unjustifiable discrimination. In the case of the shrimp–turtle dispute, the trade measure introduced by the USA required other members to adopt the same programme without taking into account different conditions in other countries. There had also been no multilateral discussions. The USA entered into multilateral talks with the main exporting countries following this ruling and a further challenge to the US legislation was not upheld pending these talks.

One of the defences that would undoubtedly be used in a challenge to an animal welfare measure would be Article XX(a), that the measure is necessary to protect public morals. There have been no cases discussed under this exception, so no definitions exist on public morals. Interestingly, recent national legislation, such as the UK's prohibition on fur farming and the USA's law prohibiting the import, export and sale of products made from cat or dog fur, were based on ethical or public moral grounds. The US Government believed that its national import ban on cat and dog fur products was consistent with its WTO obligations, citing public morals as its defence, but no challenge has been made to the legislation, so there has been no definitive view of this law by the WTO.

Since the issue of animal welfare and the WTO was first raised 10 years ago, it has been consistently stated that the WTO rules do not stop a country from implementing standards based on its own social norms. So there would be no inconsistency with WTO rules if the EU wanted to phase out battery cages. However, there is an economic consequence of raising animal welfare standards,

which would leave the domestic producer at a trade and price disadvantage when compared to imports from non-EU-country producers using less humane methods. Once this is accepted, and there have been many studies on the egg industry underlining the point, international trade implications do emerge. Far from imposing its own cultural values on other countries, the EU, which has some of the highest global welfare standards, could find the cultural values of non-EU countries being imposed on it. Two things are crucial. The determination of the economic effects of raising standards and devising a system of ensuring that any measure is least trade-disruptive.

ECONOMIC ASPECTS: PRODUCTION COSTS ARISING FROM HIGHER WELFARE STANDARDS IN THE HEN INDUSTRY

Table 5.1 summarizes the difference in production costs of five different systems using a space allowance of 450 cm^2 per bird as the baseline figure from three different studies. It underlines the effects of rising standards on production costs.

Although it is unlikely that the EU egg industry would face competition from imported shell eggs, due to transport and provenance issues (see Chapter 8, this volume), the trade in egg products from countries such as the USA or Brazil could have the potential to undermine European producers (RSPCA/Eurogroup for Animal Welfare, 2001; van Horne, 2003).

To date, additional costs arising from improved welfare conditions have been absorbed by producers or consumers for the niche market premium standards such as free-range. The existing European agricultural regime has also effectively shielded producers from non-EU-country competition. However, the reform of the CAP and the ongoing reduction in export subsidies and tariffs as part of the agricultural negotiations under the WTO has meant that other solutions to non-trade issues have to be addressed.

DISCUSSIONS UNDER THE WTO AGREEMENT ON AGRICULTURE (AOA)

Agriculture was first brought under the WTO regime as part of the Uruguay Round, the first time that multilateral trade talks included agricultural policy. Non-trade concerns were specified under the AoA's Article XX but it was not until 1999

Table 5.1. Economic consequences of raising welfare standards in the European hen industry.

Production system	% production cost difference from 450 cm^2 per hen
USA: 350 cm^2 per hen	–8%[b]; –38%[c]
EU: 550 cm^2 per hen	7%[b]; 8%[c]
Enriched cage	27%[b]; 13%[a]; 26%[c]
Barn/aviary	27%[b]; 21%[a]; 24%[c]
Free-range	58%[c]; 68%[b]

[a]van Horne (2003); [b]Williams (2000); [c]RSPCA/Eurogroup for Animal Welfare (2001).

that the EC introduced its ideas on resolving the uncertainty between WTO rules and higher welfare standards (EC, 1999). One option, to allow payments to farmers for higher welfare standards, is under discussion. The other two, allowing mandatory labelling of welfare products and to agree multilateral standards on issues such as laying hens, are outside the present negotiation or have yet to be raised. They are, however, crucial as they give flexibility for the producer.

Discussions on labelling within the WTO have not progressed much since the report from the Committee on Trade and the Environment in 1996. No decision was made on the role of mandatory labelling or whether labelling schemes that were based on non-product-related process and production methods (PPMs), such as the EU's egg-labelling scheme, are covered by the Technical Barriers to Trade Agreement (TBTA).

Labelling schemes are covered by the TBTA. Article 2.2 establishes the framework under which labelling schemes can operate. These must not create unnecessary obstacles to international trade or be more trade-restrictive than is necessary. Labelling schemes must also fulfil a legitimate objective, included in which are measures to protect animal life or health or the environment. So the TBTA recognizes that mandatory schemes are permitted and sets up a number of tests to ensure that the schemes are not obstacles to trade.

Voluntary labelling schemes do not conflict with existing WTO rules. As they are not mandatory they do not conflict with products which are not labelled. No obstacle to trade is created. This view was confirmed in the GATT decision in 1991, which looked at the legitimacy of a voluntary labelling scheme based on a non-product-related PPM. The panel found that as there was no legal discrimination between voluntarily labelled and unlabelled products in the market (in this case tuna), the labelling scheme did not restrict the sale of the product and so did not represent an unnecessary obstacle to trade.

Voluntary schemes have their limitations. A voluntary labelling scheme for shell eggs has existed for over 10 years in the European Union but research showed that consumers were still confused about the provenance of eggs on sale. The problem was that there was no incentive for lower welfare eggs to list their method of production, as this would reduce consumer demand. Use of labels with phrases such as 'farm fresh' or 'country fresh' increased consumer confusion. A mandatory scheme was introduced (Regulation EC 5/2001) for domestically produced eggs, so that all eggs sold will have to list the production method. However, crucially, the legislation avoids the issue of WTO competence because it allows producers from non-EU countries to list on their label the country of origin, leaving it to the consumer to guess what production method would have been used. Switzerland has already introduced mandatory labelling schemes for imported as well as domestically produced eggs. Both schemes have been reported to the TBTA without challenge. The EU's scheme came into effect on 1 January 2004. Clarification of the mandatory labelling schemes could also emerge from discussions on the EU's genetically modified organism (GMO) labelling regime.

Negotiations on agreed international standards on animal welfare started under the OIE (Organisation International des Epizootics/World Organization for Animal Health) in 2002 when it was agreed that animal welfare would form part of the organization's strategic objectives (see OIE, 2003). The OIE has agreed to start to look at negotiating agreements in four areas of animal welfare including slaughter and the transport of animals by land and sea. An OIE meeting in 2004

will also discuss setting standards in other animal welfare areas. A start has been made to agreeing multilateral standards for animal welfare.

The EU's proposal on agreeing payments for higher welfare schemes has made some progress since it was first introduced in 2000. The proposal to allow payments for loss of income or extra costs due to higher animal welfare standards was the only non-trade issue outlined in the summary status paper issued by the WTO in March 2003 (WTO, 2003). The deadline for agreeing the agricultural modalities is now uncertain, having been missed twice in 2003, following the collapse of talks at the Cancun ministerial. Its applicability to the egg industry is dependent on a number of factors but gained fresh momentum in June 2003 when the reform of the Common Agricultural Policy included language to allow member States to pay farmers to move over to higher welfare schemes. Laying hen producers would be eligible to claim payments for costs incurred as a result of changing over from the battery-cage system to a more extensive system. If the language on animal welfare in the status paper is adopted, such payments would also not be open to challenge at the WTO.

CONCLUSION

As trade in agricultural products is liberalized, it is important to ensure that welfare standards can continue to be improved without loss of competitiveness. The hen issue and the change-over from the intensive battery cage to a more extensive system may well be the first of many where increased costs could impact on the competitiveness of the industry. Moves away from intensive production are due to come into effect by 2014 in the pig industry. New standards in the European broiler industry could also be agreed in the next few years.

There are economic data that show the costs of improving the welfare of the laying hen, so solutions have to be found that ensure that a country can respond to consumer and public demands by raising its welfare standards and not be in contravention of trade rules. There are a number of unresolved issues regarding the relationship of trade rules and animal welfare measures. These include the mandatory labelling of animal welfare products according to the method by which they were produced, implementing differential tariffs according to method of production, and introducing market-based rules such as sales prohibitions based on production methods. The present round of negotiations on agriculture could clarify one uncertainty if it agrees that subsidies for animal welfare standards are consistent with WTO rules, thus opening up the possibility of laying hen producers being eligible for subsidies under the CAP. It is doubtful that the EU's egg-labelling scheme will be challenged, as it sets less strict rules on imported eggs than on EU-produced eggs and no challenge has yet been made to it under the TBTA. The European laying hen industry may well have two measures to partially resolve the problem of rising costs by the time that the 2005 review occurs.

Progress could also emerge in other areas, particularly to ensure that the European industry remains competitive in the egg products market. The EU should have some flexibility to ensure that tariff lines in the important egg products regimes are not reduced to such an extent that the industry becomes uncompetitive against imported products. Animal welfare suffers from having no consistently agreed multilateral standards, but this is currently being addressed under the OIE

negotiations. Although it may be many years before specific agreed standards emerge on all the farming sectors, it would be seen as positive should there be a challenge to a welfare measure, because it would indicate that such a process exists. Finally, an agreed sales ban on cosmetics tested on animals from 2009 may also provide a test of what measures are allowed to ensure that consumer concerns on the ways that goods are produced can be made to work in the market-place.

The WTO faces a crucial challenge to ensure that different national policy goals can be accommodated if domestic social and ethical polices are not to be undermined by trade liberalization. There are a number of unresolved issues still to be faced in this challenge. It is essential, not just for the European hen industry but also for the legislators and the public, that these are resolved so that higher welfare standards such as a ban on the battery cage can be introduced and be made to work within a multilateral trade environment.

REFERENCES

Anon. (1991) United States: restrictions on imports of tuna. *BISD 39S/155* (not adopted). GATT Secretariat, Geneva.

Anon. (1994) United States: restrictions on imports of tuna. *DS 29R* (not adopted). GATT Secretariat, Geneva.

EC (European Commission) (1999) Council Directive 99/74/EC laying down minimum standards for the protection of laying hens. *Official Journal of the European Communities* L203, 03.08.1999.

OIE (World Organization for Animal Health) (2003) The OIE's initiatives in animal welfare. http://www.oie.int/eng/bien_etre/en_introduction.htm

RSPCA/Eurogroup for Animal Welfare (2001) *Hard Boiled Reality: Animal-Friendly Egg Production in a Global Market*. RSPCA, Horsham, UK/Eurogroup for Animal Welfare, Brussels.

van Horne, P.L. (2003) *Impact of EU Council Directive 99/74/EC on the Competitiveness of the EU Egg Industry*. LEI, The Hague.

Williams, M. (2000) Eggs and egg products: the problems of identification of high welfare systems. In: *The Impact of the WTO on Farm Animal Welfare: RSPCA Conference*. RSPCA, Horsham, UK.

WTO (1994) *The Results of the Uruguay Round: The Legal Texts*. World Trade Organization, Geneva.

WTO (1996) US standards for reformulated and conventional gasoline. *WT/DS2/9.*

WTO (1998) US import prohibition of certain shrimp and shrimp products. *WT/DS58/R.*

WTO (2003) Summary of agricultural negotiations: the current negotiations. http://www.wto.org/english/tratop_e/agric_e/negoti_e.htm

CHAPTER 6
The food retailer–consumer relationship, with particular reference to animal welfare

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ABSTRACT

This chapter examines the relationship between retailers and consumers and the mechanisms by which food is purchased. The potential for this interaction to effect change in animal welfare standards is explored.

BACKGROUND INFORMATION

In recent years, food retailing has become very complex. There are many types of food now available which were not around 50 years ago. These are commonly categorized by food retailers in the following way, based around the storage requirements of such foods:

- Fresh – joints, chops, mince, sausages, eggs, milk
- Frozen – applicable to meat products generally
- Chilled – ready meals, cooked meats, pies, quiches
- Ambient – tinned and dried foods.

There are also many different outlets from which consumers can obtain this food which include:

- Supermarkets
- Internet shopping
- Corner shops
- Garages
- Farmers' markets
- Farm shops
- Restaurants
- Fast-food chains
- Cafés
- Public houses (pubs).

When the subject of food retailing is raised, the current focus is on supermarkets, as they are very successful, currently selling well over half of the food purchased in

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the UK. The supermarket umbrella allows competition with all of the above forms of food retailing except for farmers' markets and shops, pubs and restaurants.

Certain changes are now evident in the way consumers purchase and eat food:

- More 'further-processed' food is being eaten.
- More food is eaten out of the home.

BRANDS AND THEIR IMPORTANCE

As consumers we make many decisions before we get to the 'point of purchase', i.e. before we pick *that* product off *that* shelf. Brands are important here and trust is built over many years. It is important for the integrity of a brand that companies are able to demonstrate to customers the standards that they have in place. This communication takes place in many ways:

- Food labels, e.g. organic, free-range, Scotch beef, outdoor reared.
- Responses to direct customer enquiries by sending out leaflets, information etc.
- Presence at agricultural and food shows.
- Articles in trade journals and 'in-house' and external magazines.
- Positive media coverage, particularly in response to food scares and negative food stories.

The background work needed to achieve the ability to make this communication in a positive manner is substantial, particularly for a large retailer who will be sourcing many thousands of products from all over the world. The process which must be undertaken is as follows:

1. Formulate a company policy.
2. Set the standards in relation to the policy.
3. Implement the standards.
4. Verify the standards.
5. Review the whole process and make adjustments.

The response to customer requirements can be considered to be offered in two forms, examples of which are given below, using eggs as an example:

- Reactive – the brand is protected but nothing more, e.g. eggs are provided from all systems (cage, barn, free-range, organic) and within each system known standards are set, e.g. a requirement that UK legislation is matched wherever the product comes from in the world.
- Proactive – the brand is promoted, e.g. McDonalds UK use free-range eggs in all their products, as do Marks & Spencer. This means that where eggs are included in a product there is a requirement for suppliers to use free-range eggs. These decisions cost significant amounts of money, time and effort for both of these companies.

Traditionally, further-processed products such as cakes and quiches are made using liquid and powdered egg obtained cheaply on the world market to standards often well below those required by UK legislation.

Convenience is important to customers, who require plenty of choice under one roof, easy parking, and a fast efficient service, as evidenced by the plethora of

helpers available and tills now open in the top supermarkets. Good food safety is expected and is not generally used as a marketing tool. Interestingly 'campylobacter-free chicken' has been marketed on the continent, but sales were poor compared with 'normal' chicken. This was probably due to the fact that the majority of customers do not understand the ramifications of campylobacter, and negative marketing is rarely successful.

THE CONCEPT OF VALUE

So when consumers finally reach the 'point of purchase', what specific decisions are being made? The claim is that consumers only buy on price, and of course price is important, but the concept of value is crucial and can be described as the balance between price and quality. So which qualities are people interested in regarding their food? There has been a considerable amount of customer research in this area and results are very consistent, i.e. the qualities that people are looking for can be placed in the following categories and very broadly in the following order:

1. *Eating experience*, i.e. taste, texture, succulence, smell, appearance.
2. *Healthy*, i.e. fresh, high in vitamins, positively beneficial to health.
3. *Safe*, i.e. additive-free, antibiotic-free, pesticide-residue-free.
4. *Produced from systems which are not harmful* for animals, people and the environment.

Traceability, a well known buzz-word of our time, is merely a tool which, when used effectively, can guarantee all of the above qualities. For example, looking at the passport of a bullock in the slaughter house and seeing that he was reared on Joe Bloggs' farm tells us nothing about the welfare of the animal during his life unless linked to other information such as membership of an assurance scheme.

HOW CAN WE EFFECT CHANGE?

Animal welfare is like all other consumer issues, i.e. it competes for the money we receive each week or month and is as high on the agenda as we choose to put it. It is useful to consider who this 'we' is, and the following list gives some idea of the different types of people who have influence on this subject:

- Consumers – purchasers of food.
- Citizens – those providing the common ethic.
- Producers of food.
- Legislators.
- Non-governmental organizations (NGOs).
- Suppliers of goods and services to food producers (e.g. equipment manufacturers, nutritionists, vets, pharmaceutical companies).

It is notable that most of us are consumers of animal products and thus the vast majority of us fall into two or more categories above. The distinction between consumers and citizens is important, as it might explain the many pieces of research which show that over 80% of consumers say they are prepared to pay more for

'animal welfare friendly' products, whereas reality proves otherwise. The consumer or customer of the food retailers is of paramount importance in effecting change, as purchasing decisions drive the way in which food production operates. There are various mechanisms which can be employed to influence these vital purchasing decisions:

- Legislation, e.g. improved labelling laws to prevent misrepresentation.
- Increased understanding by education through schools, TV, farm visits etc. Where consumers are known to have understanding, purchasing decisions are seen to reflect this, for example sales of free-range eggs are now over 30% of the *fresh* egg market in the UK. Would this extend to further-processed products if there was greater understanding of food production?
- Demonstration of, and research into, improved farming systems which are shown to consumers and also to farmers and other influential bodies both at first hand and through the media.
- The sale of improved products to customers which compete with the status quo – what is next after free-range?
- Increasing the profile of the ethical aspects of treating animals and the use of peer pressure to influence both consumers and food producers (lobby organizations such as Compassion in World Farming do this with some success, e.g. battery eggs).

CONCLUSIONS

1. Many food production systems were developed at a time of food shortages and poor knowledge of animal requirements, and thus standards are low compared with our current ability to pay and our understanding of animal welfare science.
2. Food retailers sell food and are primarily driven to provide value for their customers. Most food retailers do not promote a particular type of food, only their own brand. If customers buy less of a particular type of food then this section of the brand will simply occupy less shelf space.
3. For change to occur there has to be a societal impetus, and the greatest power lies in the hands of consumers, i.e. if we buy more products which truly reflect animal welfare improvements then their market penetration increases. Food production is currently poorly understood by consumers.
4. Perhaps there are products which we would like to buy which are currently unobtainable; for instance, most of us didn't know we wanted a microwave oven so badly until they became available.

CHAPTER 7
Quality assurance

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ABSTRACT

In the UK egg industry, there has been widespread adoption of quality assurance schemes, of which animal welfare is an integral part. Welfare is addressed in terms of the system of production to be used and with reference to related issues such as beak trimming and transport time. This chapter considers the relationship between quality assurance and welfare.

INTRODUCTION

Quality assurance is now fundamental to the production and marketing of eggs in the UK but it has only recently become so. Twenty years ago the emphasis was firmly on cost of production and production efficiency. Some 95% of the national laying flock in the UK was housed in cage systems, and non-cage flocks tended to be domestic rather than commercial. Eggs were essentially a commodity and there was little attempt at product differentiation.

The changes that have occurred in recent years emphasize a changing attitude to food in general. Food purchases are determined not only by the need for nutrition but also by other factors, including animal welfare standards and the physical appeal of food. As a result, there is now much greater diversity in the systems used to produce eggs, with commercial free-range and barn systems in widespread use, in addition to cages. Non-cage systems now account for over 25% of all the eggs produced in the UK and further growth is predicted. There has also been growth in organic production and in eggs with modified nutrient content, designed to be beneficial to human health.

In a competitive market-place, quality assurance has been adopted for eggs and other foods to meet the more detailed and complex mix of consumer requirements as efficiently as possible.

Quality assurance can be defined as 'a planned and systematic pattern of all actions necessary to provide adequate confidence that the end product will perform satisfactorily'. Essentially, quality assurance aims to ensure that the requirements of the consumer or user are met, and the definition given above can be applied to a wide range of different production and manufacturing processes.

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Quality assurance requires all inputs to be carefully planned and documented, with controls and monitoring points in place to ensure that predetermined standards are achieved. In the UK egg industry, there has been a widespread adoption of quality assurance schemes in recent years. The standards set within these schemes often exceed legislation and place more emphasis upon attributes which directly determine the appeal of the product to the buyer. Animal welfare standards are important because welfare is an important factor in determining sales of eggs.

The establishment of 'production standards' has therefore become a cornerstone of quality assurance schemes. These specify the way that eggs are to be produced, in terms of the production system (cage, barn, free-range) and its key characteristics (e.g. stocking density). Other welfare-related issues such as the need for good stockmanship, environmental control and transport issues are also included.

The two most widely adopted schemes for UK egg production at present are the Freedom Food scheme and the BEIC Lion Code, although multiple retailers and other organizations also set their own standards. In addition, organic bodies set production standards relating to the production of organic eggs and these too incorporate welfare-related issues. Producers who adopt these schemes are subject to frequent audits to ensure that standards are maintained.

The Freedom Food scheme implements the welfare standards of the RSPCA. For laying hens, it covers barn and free-range egg production only, and the welfare standards adopted exceed the minimum requirements of legislation. The scheme is integrated, in that the standards apply not only to laying farms but also to pullet rearing premises and hatcheries. They also extend to transportation and to processing premises. Whilst the scheme is voluntary, the vast majority of UK barn and free-range eggs are now produced to Freedom Food or equivalent standards.

Similar requirements for non-cage systems are adopted within the BEIC Lion Quality Code of Practice, which is also a voluntary, integrated scheme. It now accounts for some 75% of the UK egg market. A key difference between the Lion Code and the Freedom Food scheme is that the Lion Code includes specifications for cage egg production, as well as for alternative systems. Furthermore, in addition to animal welfare, it covers issues such as food safety, with the compulsory vaccination of all stock against salmonella species. Eggs produced within the Lion scheme are marked with the Lion logo and with a 'best before' date.

The effects of these schemes have been considerable in altering the nature of non-cage egg production systems in particular. Key changes have included a reduction in house stocking density and the introduction of limits on flock and colony size. A requirement for the provision of litter in houses was also introduced to allow additional behavioural requirements to be met. Minimum space requirements for nestboxes were introduced and, for free-range production, minimum pophole sizes and numbers were specified. In addition to the benefits to animal welfare, these changes (which were not required within the EU egg marketing regulations at the time) were also seen as being consistent with consumers' perceptions of such systems.

Whilst animal welfare is important, consumers also have a range of other requirements which affect purchasing decisions. In some cases, the various requirements can be difficult to reconcile, as the following examples illustrate.

EGG FRESHNESS

'Freshness' of eggs is important to consumers, and whilst egg packing has tended to become concentrated at a small number of large centres around the country, the trend towards smaller unit sizes in non-cage systems means that there are more production sites in total. The need for frequent collections of eggs from numerous sites spread over a wide geographical area presents egg packers with a difficult logistical problem.

EGGSHELL CLEANLINESS

EU egg marketing legislation requires Class A eggs to be 'clean', irrespective of the system of production. The washing of Class A eggs is not permitted. A small tolerance may still remain for very minor amounts of shell soiling, but it is generally accepted that the threshold has become lower in recent years.

In non-cage systems, it is generally more difficult to maintain eggshell cleanliness. A small percentage of eggs are inevitably laid outside the nestboxes and these are very likely to become dirty. The inclusion of litter within buildings can increase the risk of floor laying through the provision of an attractive alternative to the nestbox. Even eggs which are laid in nestboxes are prone to contamination due to droppings, dust and other contaminants, and if litter quality is not maintained in a friable condition, then not only does this become a welfare issue, but some of this contamination on the birds' feet can also be transferred to nestboxes and ultimately to eggs. By contrast, in conventional cage systems, there are likely to be fewer dirty eggs because droppings fall through the cage floors and the birds' feet are generally cleaner.

In free-range systems in particular, the risks to eggs and to animal welfare are greatest during adverse winter conditions when range areas are wet and where the difficulties of maintaining litter quality are greatest.

In non-cage systems, the larger price differential between first quality (Class A) eggs and seconds makes the financial effects of downgrading much more significant. Because of this, there may be a temptation to illegally wash some dirty eggs on the farm. Figures published by DEFRA (2002) report that inspectors found evidence of some eggs having been washed in 9.6% of all batches of home-produced, non-cage eggs examined between April 2001 and April 2002. By contrast, evidence of egg washing was seen in only 1.6% of all batches of cage-produced eggs over the same timescale. Given the likelihood that the washing methods used would have been rudimentary and poorly controlled, the inclusion of washed eggs in first quality could have important food safety implications.

EGGSHELL COLOUR

Egg shell colour appears to be more difficult to maintain in non-cage systems. Whilst the EU egg marketing regulations do not require eggshells to be a particular colour, brown-shelled eggs account for almost all of the UK market. Uniformity of colour within a batch, together with a certain minimum depth of colour, are important considerations for buyers. Pale-shelled eggs are often deemed unacceptable.

Outdoor flocks are more susceptible to disease challenges which can affect shell colour and, in recent years, certain free-range flocks have been periodically affected by a 'pale egg syndrome'. This has usually occurred during the summer months and has resulted in a sudden huge increase in the numbers of eggs being downgraded. Whilst the causes are not clearly understood, anecdotal evidence has suggested that there is a link between loss of shell colour and outdoor access.

These examples set out some of the conflicts between the desire for traditional and non-cage systems of production on one hand, and the requirements for a high quality, uniform food on the other. Meeting the various requirements of today's consumer provides a challenge to the industry. The difficulties are not insurmountable but, to overcome them, emphasis has to be placed on the design of the production system and on the abilities of staff to operate it successfully.

REFERENCE

DEFRA (2002) *Egg Marketing Inspectorate Annual Report 2001–2002*. DEFRA, London.

CHAPTER 8
The producer and hen welfare

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ABSTRACT

It should not be forgotten that egg producers, whether they produce cage, barn, free-range or organic eggs, operate commercial businesses subject to the economic pressures of supply and demand. In terms of the EU's Common Agricultural Policy (CAP), eggs are subject to a 'light' regime where the only support offered is that of tariffs which are imposed on imports coming into the EU from countries not in the European Economic Area (EEA). Success of these businesses is not guaranteed; failure is a real possibility.

There are three important drivers which influence producers' behaviour. Firstly, and most importantly, it is consumers who will determine the types and quantities of eggs produced. It is consumers who decide the 'what'. The second driver, legislation, sets the minimum standards – the 'how'. The weakness of legislation, however, is that it is not global – for the UK it is either national or EU. In the increasingly globalized trading environment that exists today it is the third driver, therefore – the World Trade Agreement – which will determine the 'where'.

The UK egg industry already has one of the largest alternative market shares in Europe (mainly free-range) and that is forecast to grow significantly over the next 10 years, again mainly in the free-range sector. Cage eggs represent 70% of the market currently and whilst this will decline as the alternatives grow, it is still expected to be the biggest market sector in 2012 at around 50%.

Different pieces of legislation are increasing the cost of all types of egg production in the EU according to varying timetables. The cost end-game of all the EU Directives and Regulations is currently due to be achieved at the end of 2011. The welfare standards (and costs) in Europe far exceed those anywhere else in the world.

At the same time another round of WTO negotiations is under way which will inevitably reduce our protected status with regard to imports from non-EEA countries. Under current WTO rules one cannot ban imports from non-EEA countries that do not meet UK welfare standards. Whilst it is the intention of the EU to introduce welfare standards into the new WTO proposals, it is the express intention of many of our trading partners not to allow it.

On a worldwide basis, traded egg is cage egg, and the most price-sensitive market is for eggs used in processing. In the EU we need a viable low-cost production system, which the enriched cage offers, for the processed and value markets. It is the outcome of the WTO negotiations and the 2005 review of the Welfare of Laying Hens

©CAB International 2004. *Welfare of the Laying Hen* (ed. G.C. Perry)

Directive which will determine whether that egg is produced in the EU or imported from non-EU countries where welfare standards are much lower than those currently pertaining in the UK, let alone the new standards we are moving towards.

LEGISLATION

Normally one would start first with consumers, since the market is the most important driver, but in this chapter it is probably better to start with the legislation, since this is going to have such a profound effect on costs, and therefore also on the market.

There are many pieces of welfare legislation which impact upon egg producers. Mainly these arise from EU Directives or Regulations, which may or may not be 'gold-plated' when they are transposed into national legislation. Within the UK there is an added complication that animal welfare is a devolved issue so that we have, for example, four pieces of legislation – English, Welsh, Scottish and Northern Irish – to implement the EU's Welfare of Laying Hens Directive (WLHD).

Whilst there is welfare legislation on transport, slaughter and on animal health, this chapter considers the effect of three pieces of legislation:

- the EU Organic Regulations (EC 1804/99 supplementing EEC 2092/91);
- the EU Egg Marketing Regulations (various);
- the Welfare of Laying Hens Directive (1999/74/EC);

as implemented by the respective national legislations.

Table 8.1, produced by the British Egg Industry Council (BEIC), shows the impact of the Welfare of Laying Hens Directive on the costs of egg production. It is worth noting that all costs will rise – cage, barn and free-range – between now and 2012, when all the measures in the Directive are completed. The enriched cage will be the cheapest form of egg production in 2012. Also included in Table 8.1 are some figures for multi-tier barn systems. These systems are not currently used in the UK but do find some favour in certain other EU member States. They

Table 8.1. Impact of the Welfare of Laying Hens Directive on the costs of egg production.

Stocking density	Capital cost (£ per bird)	Running cost (pence per dozen)
Cage 350 cm^2 per bird	10.00	38.0
Cage 450 cm^2 per bird	14.00	41.3
Cage 550 cm^2 per bird	14.25	41.4
Enriched cage 750 cm? per bird	20.30	46.1
Barn – single level (based on 12 birds/m^2 ground floor)	14.73	52.2
Barn – single level (based on 9 birds/m^2 ground floor)	19.14	57.5
Barn – multi-tier (based on 12 birds/m^2 ground floor)	21.03	55.6
Barn – multi-tier (based on 20 birds/m^2 ground floor)	21.87	52.3
Free-range – single level (based on 12 birds/m^2 ground floor)	20.61	62.4
Free-range – single level (based on 9 birds/m^2 ground floor)	25.00	69.3

have been advocated by some welfare organizations as 'the way forward' (as compared to enriched cages).

It should be remembered that when non-cage systems were first developed in the UK – in the early to mid-1980s – several high-density, multi-tier systems were used. The mindset of the time was 'Here is a former cage house which used to contain X thousand birds. How can we design a non-cage system to accommodate as nearly as possible those X thousand birds?' This mindset might still apply in those EU member States where they find favour today. The UK industry, however, quietly abandoned all their multi-tier systems because they simply did not work, and went over to the single-tier systems that are virtually universally used today. It is accepted that today's multi-tier systems are not the same as the ones previously abandoned and that one should keep an open mind on these issues, informed via meaningful research. To propose them as the current panacea for all ills is, however, reckless in the extreme.

Figure 8.1 shows the cost effects of both the WLHD, the organic regulations and the egg marketing regulations, along with the operative dates. The costs are shown in Table 8.2. These cost increases are the farmgate increases in cost of all the eggs that a hen produces. It is misleading to apply these figures, as certain welfare organizations do, to annual *per capita* egg consumption figures (180 in 2002) and then say 'it would only cost consumers just over £3 to convert from cage to free-range eggs'.

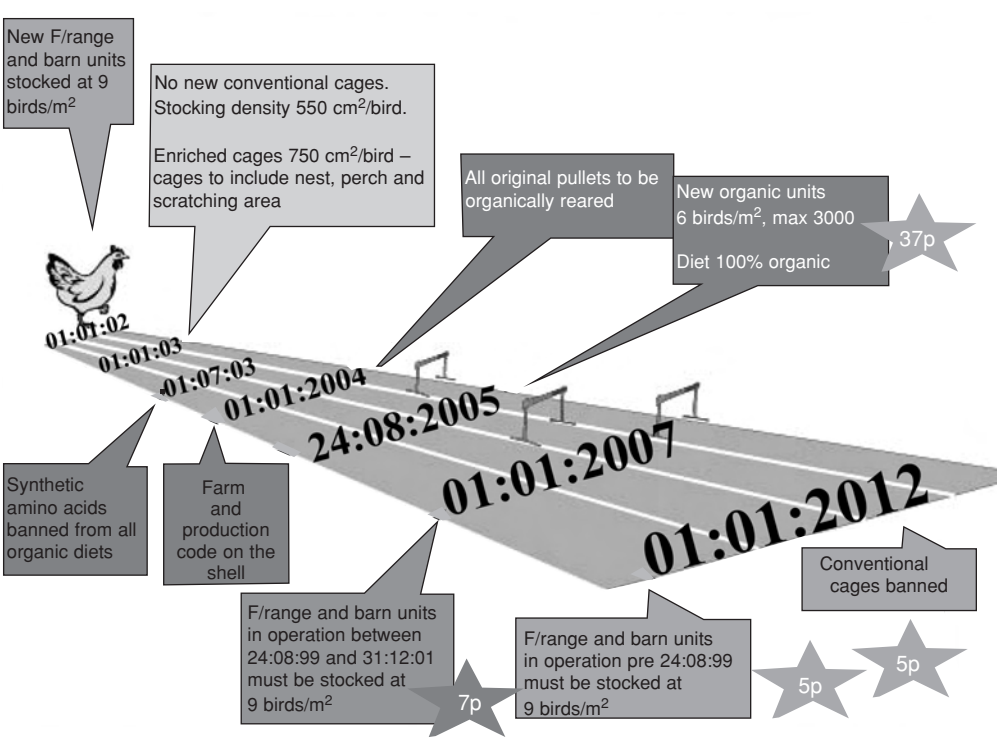

Fig. 8.1. Cost effects of the Welfare of Laying Hens Directive, the organic regulations and egg marketing regulations and the operative dates.

Table 8.2. Cost increases by 2012 due to legislation.

	Current cost (pence per dozen)	Cost increase by 2012 due to legislation
Cage	41.4	+4.7
Barn	52.2	+5.3
Free-range	62.4	+6.9
Organic	85.0	+36.7

There are substantial cost differences from farm to the supermarket shelf to take into account; in particular, the downgrading of premium eggs from premium egg sales due to their size or quality or due to the variability of market demand, which means running surpluses to meet peak levels. These surpluses would normally be cascaded down, subject to sales requirement, into lesser production types, e.g. organic to free-range, free-range to barn, etc. With the advent of the marking of production type on the egg this may no longer be possible. The cascade works for the benefit of alternatives and its loss would damage the economics of non-cage eggs.

CONSUMERS

Consumers dictate what is produced; and producers should do that to the best of their ability, whatever system is operated. In 2002 the market split in the UK according to Department of Environment, Food and Rural Affairs (DEFRA) statistics is shown in Table 8.3. There are three sectors which go towards making up those figures; retail, food service and processing. Of the eggs consumed in 2002, 64% were from the retail sector, 18% food service and 18% processed.

Table 8.3. Egg production systems in the UK in 2002.

Organic	2%
Free-range	22%
Barn	6%
Cage	70%
Total	**100%**

Figure 8.2 shows the estimated demand by egg type and market sector in 2001/2002. This shows that currently non-cage-produced egg is only significant in the retail sector. Penetration of non-cage eggs in the food service and processed sectors is low and that which exists is due almost exclusively to two companies – McDonalds UK in food service and Marks & Spencer in processing.

Looking into the crystal ball to see where the market split might be in 2012 (when all the current welfare issues are completed), it is necessary to forecast changes both within each sector and also the relative sizes of those sectors. A 'guesstimate' of the market split in 2012 is shown in Table 8.4.

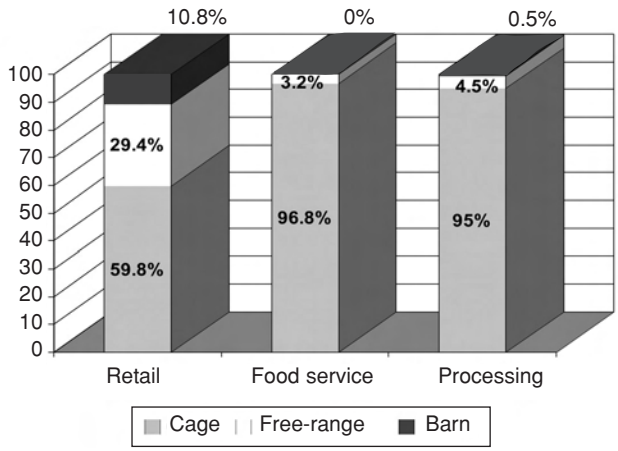

Fig. 8.2. Estimated demand by egg type and market sector (2001/02).

What reasoning lies behind these figures? Firstly, for organic egg production there is a real problem. Whilst all costs of production are going to rise as a result of legislation, organic production is going to increase at a massively disproportionate rate. Even though organic egg has been the fastest growing sector over the last few years, when those ex-farm prices are translated into the retail price increases that consumers actually pay they may kill off further growth in organics, and may even lead to an overall decline in the size of the organic egg share of the market.

Table 8.4. An estimate of the market 'split' in 2012.

		Change 2003–2012
Organic	2%	No change
Free-range	40%	+18%
Barn	8%	+2%
Cage	50%	–20%
Total	100%	

With free-range eggs, substantial growth is foreseen. This rate of growth at 2% per annum is faster than we have seen previously and so this is an optimistic forecast. Free-range growth in the retail sector is not yet complete, although a plateau will eventually be reached which will vary according to customer profile, but significant growth is foreseen in the food service and processing sectors. These sectors are themselves growing, with retail static (but no longer declining).

Barn production is the most difficult product to forecast. The barn egg remains the 'Cinderella' product which consumers do not understand. Most consumers will have a perception of cage and free-range egg production but cannot envisage what barn production entails. Personal experience of consumer perceptions of cage and free-range is that they are wrong in both cases. When showing non-poultry people

around farms, cage production almost always comes across as 'nothing like as bad as they expected', and with free-range the expectation is of small groups of birds (under 100) rather than thousands.

Given the buying public's lack of understanding of the barn sector, there may be only a very modest increase in barn production by 2012. This growth is all in the retail sector; there is no barn requirement to speak of in food service or processing and that is unlikely to alter.

The forecast for cage eggs by 2012 at 50% is based on it being rather less than half of retail (approximately 40%) but still predominant in the growing food service and processing sectors (approximately 70%).

WORLD TRADE AGREEMENT

The big question is 'will that egg be produced here or will it be imported'? The answer to that question depends on the outcome of the current World Trade Organization (WTO) negotiations and the outcome of the review of the WLHD in 2005. Producers cannot complain about competing on the proverbial 'level playing field'. The problem is that the playing field is already tilted against them and the current European welfare legislation disadvantages them yet further. Cage egg dominates the world scene and on a worldwide basis traded egg is cage egg. It must also be remembered that it is the EU, not the UK, which sits at the WTO negotiating table. In the WTO proposals currently on the table, payments for the additional costs of welfare legislation would be permitted via the 'Green Box'. Whether that remains in the final agreement is absolutely key to producers. However, even if it does, it is by no means certain that any assistance would actually be forthcoming, due to budgetary constraints both at EU (Common Agricultural Policy) and UK levels.

There is a very real fear amongst producers that, when it comes down to the inevitable horse-trading as the current WTO round is concluded, agriculture is unimportant to both the UK and the EU (as compared, say, with services and manufacturing) and that egg producers will be offered as the sacrificial lamb to secure a deal in other areas.

To illustrate the problems facing the egg industry, the BEIC, along with the egg trade associations of Spain, Italy and The Netherlands, commissioned a study by P. van Horne and N. Bondt of the LEI in The Netherlands (van Horne and Bondt, 2003). This study looked at the current competitiveness of EU-produced egg and also how this could change under a variety of scenarios by 2012. There are, in fact, eight different traded egg product lines, although the study concentrated on just two – whole eggs in shell, and whole egg powder. The study looked at the cost of eggs delivered to Frankfurt.

Figure 8.3 shows the current costs for supplying shell eggs to Frankfurt; it can be seen that, although the EU's production costs are the highest of the countries chosen, when you add in the transport costs and the tariff then the EU egg works out as the cheapest. The situation for whole egg powder is currently also relatively safe (see Fig. 8.4) but India is already marginally cheaper.

Under WTO rules there are some reduced tariffs (50% of normal levels) for limited fixed volumes – the Tariff Rate Quantities (TRQ) – which are meant to represent 5% of the market. Whilst the current TRQs on shell egg are hardly

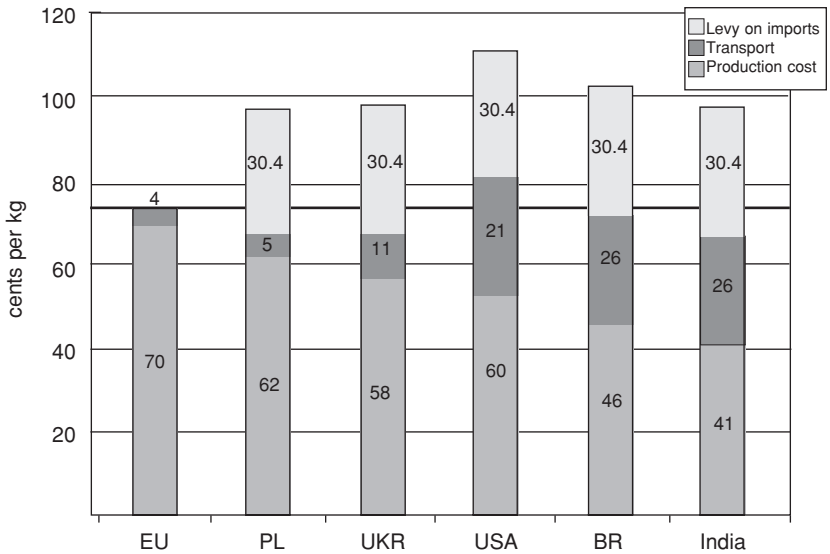

Fig. 8.3. Shell egg prices in Frankfurt in 2001.

ever used, those for powders are, not surprisingly, almost always used to the full.

The scenario chosen here for 2012 is one which assumes the following:

- EU feed cost down 5% due to the CAP mid-term review.
- Appreciation of the euro by 15% against trading countries' currencies.
- 36% reduction in tariffs (as per the last WTO round).

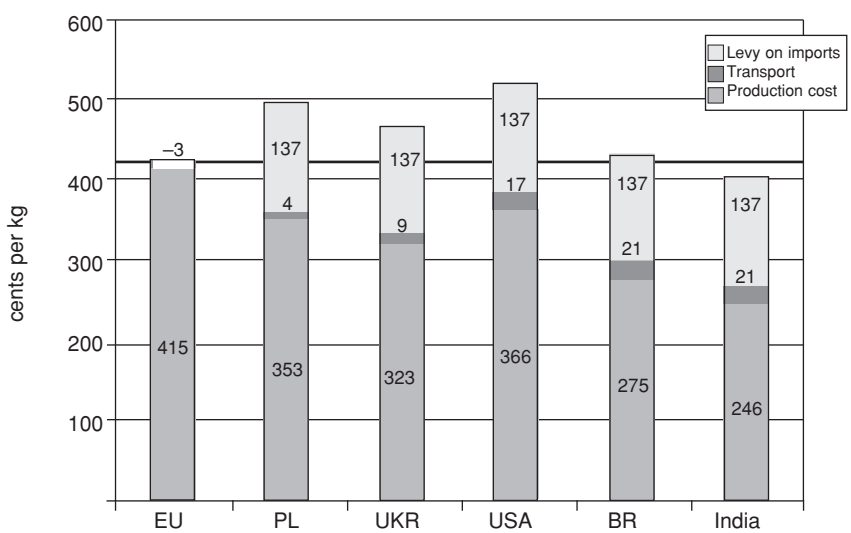

Fig. 8.4. Whole egg powder prices in Frankfurt 2001.

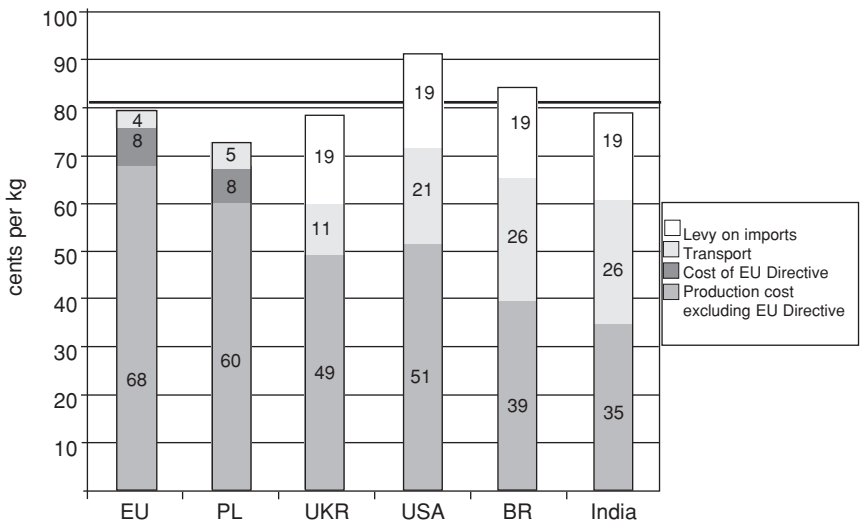

Fig. 8.5. Estimated shell egg prices in Frankfurt in 2012.

The current WTO proposals go further than the scenario above, with an average 50% reduction envisaged. Under this scenario for shell egg in 2012 there are some problems. Poland, although cheaper, will then be in the EU and so is not relevant. Ukraine is competitive. The scenario shown in Fig. 8.5 would suggest that the TRQs would be used on shell egg in these cases.

This study looked at full costing. In many circumstances, however, export business takes place at a loss due to dumping to protect home markets – thus one might surmise that under this scenario there would also be an element of imports at full tariffs from countries in surplus.

The situation for whole egg powder under this scenario in 2012 is simply dire, as shown in Fig. 8.6. At an EU level the processing sector amounts to 25% of EU production (compared with 18% currently in the UK). Again, on an EU basis, the processing sector currently comprises approximately 25% powders, the balance of 75% being in fresh or frozen products. This is forecast to reverse by 2012 so that food manufacturers, who are often pan-European, can take advantage of low-cost egg powders from around the world. It is not surprising that the egg industry in both the UK and Europe is making the case as strongly as it can for eggs, particularly in powdered form, to be treated lightly in the current WTO round.

It is against this background that the EU will have to review the WLHD in 2005. By then, of course, we will be an EU of 25 member States and that in itself will introduce a whole new set of opinions. There is 'a head of steam' building in the southern member States which says, for cage eggs, '550 cm^2 per hen and no further'. At the same time we have the gold-plating of Germany, which bans conventional cages at the end of 2006 and enriched cages by 2012. There is now an increasing view that Germany will alter its position when it reviews its own legislation in 2005, at the same time as the EU review.

One of the problems caused by the WLHD is the sheer cost of it. Due specifically to the height requirement of 45 cm for an enriched cage, it will require all cages to be replaced, since it is not feasible, from an engineering point of view, to

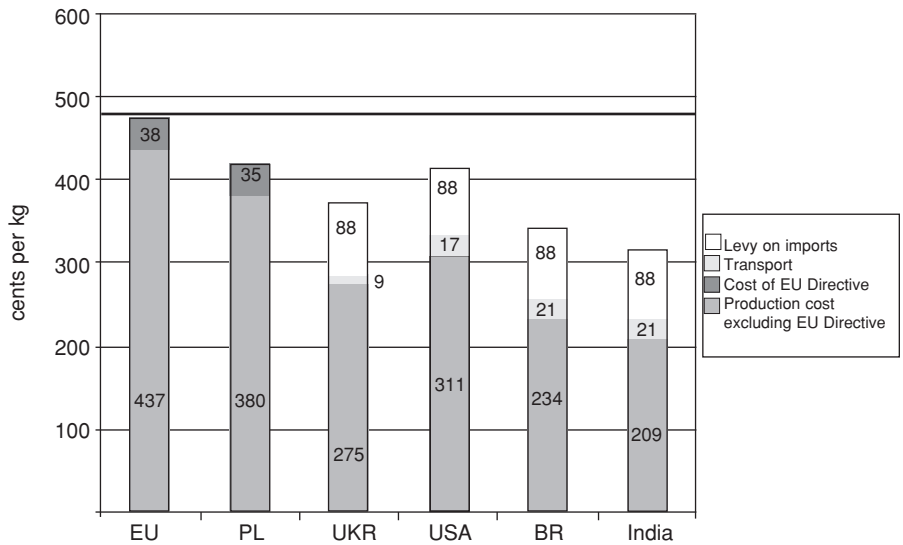

Fig. 8.6. Estimated whole egg powder prices in Frankfurt in 2012.

add height to cages. Interestingly the capital cost is similar, at around £20 per bird place (excluding land in the case of free-range), for any 2012-compliant system – enriched cage, barn or free-range single-tier at 9 birds/m and barn multi-tiers at greater stocking densities. This cost of approximately £20 per bird is, however, for totally new systems rather than, say, re-caging an existing cage house with enriched cages.

The BEIC estimate of the capital cost of the WLHD is £431 million, which is in close agreement with the Government's figure of £409 million produced in its regulatory impact assessment. Both these assessments included elements of re-caging as well as new building.

The question is 'where is the money going to come from'? There is a capital bill of approximately £430 million to find over the next 9 years. In a good year egg producers will make, say, £10 million at farm level, and farm level is the relevant indicator since the expenditure will be on-farm. How can producers be expected to find capital at five times their *good* year profits for the next 9 years to comply with the Directive? Until now the egg industry has been a subsidy-free zone, but unless some form of assistance is available to make the transition, then a major shortfall in domestic egg availability can be foreseen which will throw open the market to imports, regardless of the outcome of the WTO negotiations.

The UK needs a low-cost egg production system in its portfolio and it seems that the enriched cage will fulfil that. What is exciting us as producers is the progress that has been made on enriched cage design in the short time since the Directive was agreed. In particular, larger enriched cages with colonies of up to 60 birds are showing considerable promise. While the space per bird remains unchanged at 750 cm^2, the larger unit size allows much better organization of space, with separated nesting, perching and scratching areas. Due to the use of shared space, many more individual bird behaviours are possible, such as wing stretching, wing flapping and so on. There is a *potential* risk of feather pecking

and cannibalism due to the larger colony sizes, but early information on this is very encouraging. It is, of course, still a small colony when compared to our barn or free-range birds, where colonies in their thousands are the norm. These larger colony cages are an enriched cage system which needs further investigation, although time is now short if it is to contribute to the 2005 review.

REFERENCE

van Horne, P.L.M. and Bondt, N. (2003) *Impact of EU Council Directive 99/74/EC 'welfare of laying hens' on the competitiveness of the EU egg industry*. LEI, The Hague, The Netherlands.

PART II
Overviews

CHAPTER 9
The laying hen: systems of egg production

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ABSTRACT

Early last century, egg production was based on small flocks kept extensively on mixed farms alongside other livestock and crop enterprises. As farming became more specialized, average flock size increased and semi-intensive systems emerged, in which hens were kept in houses with littered floors, often with outdoor access. Various more intensive systems incorporating perforated floors to separate hens from their faeces were developed around the middle of the last century. Laying cages followed, first for single birds and soon after for small groups of birds.

The debate on animal welfare in many countries and, in particular, the intense criticism of laying cages, the most widely used egg production system, has stimulated many developments to enhance cage design, improvements to alternatives and the emergence of new systems. These developments have generally been gradual and well thought out. In recent years, EU Directives for the protection of laying hens, and accreditation schemes, have further influenced system design and management.

A variety of production systems are currently available, including conventional and enriched (furnished) laying cages, alternatives such as aviaries, percheries and deep litter, and free-range production in fixed or mobile houses. Welfare can be satisfactory in each of these systems, if they are well designed and managed, but currently pullet chicks destined for alternative systems have to be beak trimmed at under 10 days of age to minimize the risk of feather pecking and cannibalism. Production costs are lowest in cages and highest on free-range.

BACKGROUND

Early last century, egg production was based on small flocks of hens kept outdoors on mixed farms alongside other animal and crop enterprises. As farming became more specialized, the average flock size increased and hens were kept mainly in houses with littered or part-littered floors, often with access to an outdoor enclosure. Parasitic disease problems occurred commonly when many hens were kept on litter or land in confined areas. Various perforated floored systems (mainly timber slats or wire mesh) were developed in the 1930–1950 period to separate hens from their faeces and thus minimize the risk of parasitic disease. However,

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these systems often resulted in problems of hysteria, feather pecking and cannibalism. The deep-litter system, first operated as an all-litter floor and later on two levels comprising part littered/part raised perforated floor areas, gained popularity for large-scale egg production.

During the 1930s the first commercial cages for laying hens were developed in the USA; these were designed to house single birds and consisted of a wooden framework with wire mesh floors. Feed and water provision, egg collection and manure removal were all done by hand. Laying cages gradually evolved in Europe during the 1930s and 1940s and many were constructed almost entirely of metal. The detailed design of early cages was not ideal and birds were sometimes trapped, resulting in injury or death. However, hygiene was significantly better than in alternative systems, parasitic diseases virtually disappeared and injurious pecking and cannibalism were reduced considerably. After many years of design improvement, mortality due to accidents and trapping in modern cages has been reduced to a very low level.

During the 1940s, many laying flocks moved from free-range and semi-intensive systems to deep-litter houses, wire-floored houses or a combination of the two. During the 1950s and 1960s there was a rapid and sustained change towards laying cages. This took place, in particular, to simplify management but was also prompted by welfare and disease problems which were then prevalent in the verandah, straw-yard, deep litter and wire floor systems. Initially these cages were for single birds, but in the early 1950s twin-bird cages became popular and multi-bird cages soon followed. This trend continued during the 1960s and 1970s (see Fig. 9.1 for the UK figures). During this period the economic and welfare benefits of higher winter house temperatures were discovered, and the number of tiers of cages and stocking density in laying houses therefore increased. Also during this period the realization that there were production benefits from the use of controlled lighting patterns led to the common adoption of windowless, artificially lit housing. Improved house insulation was adopted to prevent condensation at

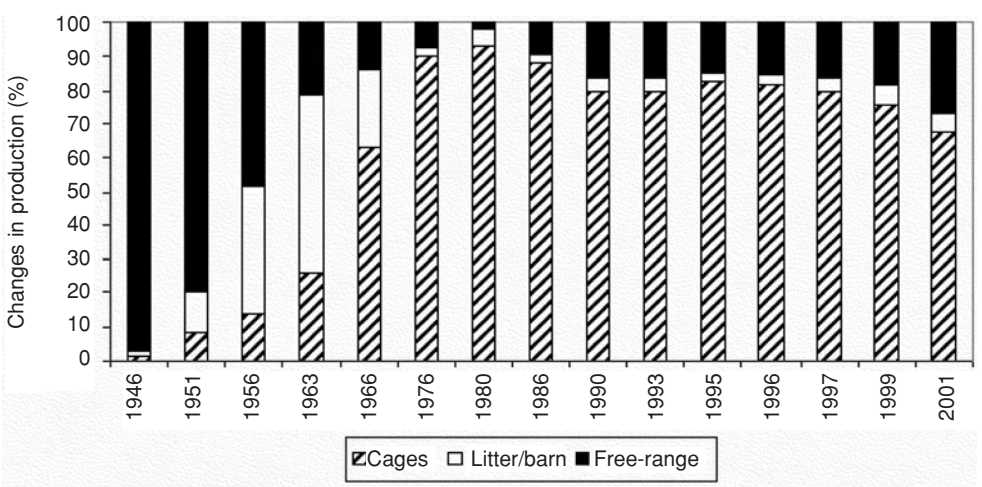

Fig. 9.1. Changes in UK egg production systems, 1946–2001 (adapted from data of MAFF and DEFRA and the Museum of the British Poultry Industry).

higher stocking densities and fan-controlled ventilation systems were introduced to cope with excess heat in summer. The result was the emergence of controlled environment housing which has continued in use until the present, but with increasing automation of control systems.

As cages, in various configurations, came into general use, feed and water provision, as well as egg and manure removal, were increasingly mechanized. Today most commercial egg production (well over 90% in the USA and Europe) is derived from caged hens. However, there is an increasing awareness in many countries that hens in conventional cages are restricted to some extent in their freedom and ability to fully express the full range of their normal behaviour patterns. This has led to increasing public concern in some areas about the continued use of cages in their present form. European Union (EU) Council Directive 99/74/EC (EU, 1999), which has been implemented by the national laws of most member States, requires all laying cages in use after 2011 to be enriched by the addition of nest-boxes, perches, littered pecking and scratching areas etc. It also introduces more stringent requirements for alternative systems. These requirements could be amended for some or all systems in the light of new information, when the review of this Directive is completed by the end of 2004.

The debate on animal welfare and, in particular, the criticism of conventional laying cages, has stimulated many developments in the enhancement of cages, improvements to existing alternatives and the emergence of new designs. In all systems, management as well as design are important for good performance and bird welfare. For various reasons, production costs are higher in alternative systems than in laying cages. An indication of these is shown in Table 9.1.

Table 9.1. Egg production costs guide in different systems.

System	Stocking density	Cost (% of conventional cage: 450 cm^2 per hen)
Conventional cage	450 cm^2 per hen	100
Conventional cage	550 cm^2 per hen	104
Enriched cage	600 cm^2 per hen	108–110
Enriched cage	750 cm^2 per hen	110–112
Aviary/perchery (barn)	12–18 hens/m^2	112–115
Aviary/perchery (barn)	9 hens/m^2	116–118
Free-range	1000 hens/ha	140

(After Elson, 1985, 1992; Haartsen and Elson, 1989; van Horne, 1996.)

Over the years, in many European countries, the proportion of hens in cages increased to a peak in the early 1980s and has since declined. Taking the UK as an example, the percentage of eggs from hens in different systems were as shown in Fig. 9.1.

CONVENTIONAL LAYING CAGES

The conventional laying cage is usually a small enclosure with a sloping wire mesh floor and ancillary equipment for feeding, drinking and egg collection mounted on the front. It may appear that little change has taken place during the past half-century since battery cages took over from traditional non-cage systems as the most popular method of egg production. However, there have been several changes in the detail of cage design and construction to improve production and efficiency and enhance bird welfare.

One of the major points, which has given rise to public concern, is the degree of confinement of laying hens in cages. In some countries the area allowed per bird has increased in recent years and EU Directives 88/166/EEC (EU, 1988) and 99/74/EC (EU, 1999) have helped to achieve this. However, a wide range still exists in multi-bird cages from under 350 cm^2 per hen in the USA to 450–550 cm^2 per hen in most of Europe and 600–700 cm^2 per hen in Scandinavia. Studies on the space requirements of laying hens by Faure and Lageric (1989), using an operant conditioning technique, indicated that the motivation of hens to work for a space of more than 400 cm^2 (four hens in 1600 cm^2) is low, although some hens did work for 625 cm^2 each (four hens in 2500 cm^2). Since 1988, most manufacturers have redesigned their cages and in doing so have produced a cage which is approximately 50 cm square, giving a cage area of about 2500 cm^2.

There is a difference in interpretation in different member States of what constitutes the regulation 'cage area … which may be used without restriction' especially in relation to the area occupied by a deflection plate. In practice, deflection plates are fitted immediately behind the feed trough and generally protrude 5–10 cm into the cage. In the national laws of Belgium, Germany, The Netherlands and the UK, the area occupied by such deflection plates can be included as cage area, but in those of France and Italy it cannot. The EU Scientific Veterinary Committee considered this matter and concluded that the area occupied by such deflection plates allows most behaviours found in cages and should therefore be included in the cage area (Blokhuis *et al.*, 1997).

Increased area per hen is one of two new cage requirements in EU Directive 99/74/EC (EU, 1999). The other is for the provision of a suitable claw shortening (CS) device. Conventional (unenriched) laying cages must now comply with the following criteria:

- at least 550 cm^2 cage area per hen, 65% of which must be over 40 cm high and all of which must be over 35 cm high;
- at least 10 cm feed trough length per hen;
- at least 10 cm drinker trough length per hen or at least two nipple or cup drinkers within reach of each cage;
- a floor with a maximum slope of 14% or 8 degrees, which adequately supports the forward-facing claws of each foot;
- a suitable CS device.

Extra Area

The increase from the previous requirement (EU Directive 88/166/EEC) of 450 cm^2 per hen to the current one of at least 550 cm^2 per hen can be achieved in one of three ways:

1. Reduce the number of hens per cage – typically in a modern 50 × 50 cm cage from five to four hens – a reduction of 20%.
2. Double the cage size by opening suitable popholes in alternate side partitions in 50 × 50 cm cages to accommodate nine hens – a reduction of 10% (Elson, 2001). The disadvantage of this method is that the larger colony size is more difficult to manage and introduces a greater risk of cannibalism and egg quality problems.
3. Deepen the cages sufficiently to retain five hens per cage. In most 50 × 50 cm cages this can be achieved by fitting specially designed bowed-out replacement cage fronts, which are available to fit most modern cage types (Elson, 2002a). This is the most popular approach in the UK, since it maintains the current colony size, performance and house temperature. As with other cage modifications, the fitting of bowed-out fronts requires careful subsequent observation and management to ensure that bird welfare is not put at risk.

Suitable Claw Shorteners

It has long been known that, when feeding in cages, birds usually stand with one foot on the floor and the other on the deflection plate or the back of the feed trough. This is presumably part of their foraging behaviour that involves pecking and scratching at or near feed. It is also known that hens' claws overgrow in cages because they do not have access to the abrasive materials that are available in some more natural surroundings. This can result in trapped and/or broken claws. Work in Sweden, where claw shorteners (CS) have been compulsory in laying cages for several years, and subsequently in the UK, showed that the application of a narrow abrasive strip about one-third of the way down the deflection plate from the back of the feed trough effectively shortens and blunts the claws on the three forward-facing toes (Tauson, 1986; Elson, 1990). CS of various types, e.g. abrasive paste, ceramic strip, coined steel plate, tungsten carbide coated plate, small holes punched in steel plate, emery cloth and abrasive tape, are now available from several manufacturers (Elson, 2002b); they should be effective, durable, kind and economic. A recently completed monitoring exercise involving all the above types indicated that, if correctly fitted, most can be effective and suitable (Elson, 2002b, 2003). Some CS are more durable than others so this exercise will continue in order to test their effectiveness during a second laying cycle.

Facilities for Inspection and Removal of Hens

Laying cages may be arranged in various configurations within a battery from flat-deck (single-tier) through stepped and semi-stepped layouts to vertically stacked arrangements, usually with cages mounted back to back from three to nine tiers high. The Annex to EU Directive 99/74/EC (EU, 1999) requires that 'accommodation comprising two or more tiers must have devices or appropriate measures must be taken to allow inspection of all tiers without difficulty and facilitate the removal of hens'. Whilst various items of equipment such as trolleys, steps and rails have been used to this end, they can be unsatisfactory. A fixed catwalk or gangway halfway up a six-tier block of cages, for example, making them effectively two sets

of three-tier cages one above the other, is much more satisfactory. This arrangement, with an appropriate aisle width, could also allow transport containers to be taken to the cages, thus simplifying housing and depopulation of hens and reducing handling damage.

ENRICHED LAYING CAGES

Due to welfare concerns over the barren nature of conventional cages in which some natural behaviours are prevented or modified, efforts have been made to provide perches, nestboxes, dust baths and/or littered scratching areas, claw shorteners and more space in laying cages. Such efforts led to studies of get-away cages (Elson, 1976; Wegner, 1990; Rauch, 1993), terraces (Elson, 1989; van Niekerk and Reuvekamp, 1995) and modified enriched cages (Appleby, 1993; Elson, 1993; Abrahamsson *et al*., 1995; van Niekerk and Reuvekamp, 1995). In research circles the latter are generally described as furnished cages because this is an objective definition (Abrahamsson, 1996). In legislation they are described as enriched cages (EU Directive, 1999; WOFAR, 2002).

Enriched cages have been, and are currently being, studied at research centres in several EU member States. Although the original concept was British, it was rapidly taken up in Sweden where Research & Development and monitoring phases under the auspices of the Swedish Board of Agriculture have resulted in four cage models being approved for commercial use (Tauson and Holm, 2001). By March 2002 10–15% of the national laying flock in Sweden were housed in enriched cages on 40 farms (Tauson *et al*., 2002); since then the proportion has increased considerably and by the end of 2003 all caged hens in Sweden will be in enriched cages. The approved Swedish enriched cages are all for small colonies of about eight to ten hens and most have side nestboxes.

In other countries enriched cages are still at the development stage (Fiks van Niekerk *et al*., 2002). There are no large-scale commercial installations in the UK yet (although at least one is planned) but some commercial-scale testing is ongoing (Walker *et al*., 2003). Meanwhile, all installations of enriched cages in the EU must now meet the criteria required by EU Directive 99/74/EC (EU, 1999), and in England by WOFAR, 2002. These include a minimum area of 750 cm^2 per hen, at least 600 cm^2 of which will need to have a minimum height of 45 cm. The remainder, which will probably form a nestbox with possibly a scratching area above, will have to be at least 20 cm high. Hens must have a nest, litter so that pecking and scratching are possible, appropriate perches allowing at least 15 cm per hen, at least 12 cm length of feed trough per hen, an appropriate drinking system (if nipple or cup drinkers are used at least two must be within reach of each hen) and a suitable CS. To facilitate inspection, installation and depopulation of hens, there must be a minimum aisle width of 90 cm and a space of at least 35 cm between the floor of the building and the bottom tier of cages.

As the design and technology associated with enriched cages evolves, so research and experience must advance in order to maintain its relevance to the industry and policy makers. A significant development in enriched cage operating practice at present is the use of larger colonies. From experience gained from a German trial, it seems possible that colonies of up to 60 hens in certain designs may be feasible and easier to manage. However, this approach needs further study

and has therefore been included in a current UK farm trial on various designs of enriched cage. In the UK and Sweden most research to date has been conducted with colony sizes between six and ten hens; there is evidence that in these productivity and welfare is as good as, or better than, that of hens in conventional cages (Appleby *et al*., 2002; Drakley *et al*., 2002).

In a recent flock in furnished cages at ADAS Gleadthorpe, UK, an assessment was made of the effect of stocking density and minimum cage height on bird welfare and performance. In beak-trimmed hens there were no major differences in performance or welfare as indicated by production, behavioural or physiological indicators. As reported by Drakley *et al.* (2002), there was no significant effect of cage height on rate of lay but there were significant effects of stocking density on feed intake and rate of lay (possibly related). This study is currently being repeated with two hybrids with intact beaks. Stocking densities ranged from about 600 to about 1000 cm^2 per hen. The results will be used by the UK Department of Environment, Food and Rural Affairs (DEFRA) to inform the review of EU Directive 99/74/EC (EU, 1999), which is due to be completed by the end of 2004, to enable the Commission to report to the Council of Ministers by 1 January 2005, as required.

ALTERNATIVE SYSTEMS OF EGG PRODUCTION

The term 'alternative systems' is used in EU Directive 99/74/EC (EU, 1999), to describe all systems other than laying cages. WOFAR, 2002, which implements the Directive in England, uses the term 'non-cage systems' to describe them. Several 'alternative' systems were in use before the cage system was developed; these mostly comprised the less intensive ones. Some other more intensive systems have been developed over the past 25 years or so, e.g. aviaries and percheries, now often grouped together as barn systems.

It should be noted that all alternative systems are required to provide the birds with nests, litter and perches as well as appropriate feeders and drinkers. A summary of the requirements of EU Directive 99/74/EC (EU, 1999), which apply to new installations and existing ones in due course is:

- at least 10 cm per hen for linear feeders or 4 cm per hen for circular ones;
- 2.5 cm per hen for continuous drinking troughs or 1 cm per hen for circular ones, or at least one cup or nipple drinker for every ten hens;
- at least one nest for every seven hens or at least 1 m^2 of group nest space for a maximum of 120 hens;
- at least 15 cm per hen of adequate perches without sharp edges;
- at least 250 cm^2 of littered area per hen, the litter occupying at least one-third of the ground surface;
- stocking density must not exceed 9 hens/m^2 of usable area;
- floors constructed to adequately support each of the hens' forward-facing claws;
- where hens can move freely between different levels:
  - there shall be no more than four levels
  - the headroom between the levels must be at least 45 cm
  - droppings must not fall on the levels below
  - drinking and feeding facilities must provide equal access for all hens.

In the UK, additional welfare standards apply to a large number of egg producers who are in accredited certification schemes, e.g. Freedom Food Ltd (RSPCA, 2002) and the Lion Quality Code of Practice (BEIC, 2002).

An up-to-date description of various alternative egg production systems follows, together with relevant information on stocking density and some management and design considerations. Most of these systems have been illustrated by Elson (1995).

Indoor Systems

Such systems may have one floor, or several levels. McBride (1970) suggested that 'it should be possible to design houses which have many tiers of lattice floors'. A few years later such systems were proposed and tested in several countries. They included aviaries and percheries. Systems in current use include:

- aviaries of various types;
- percheries with a variety of layouts;
- covered straw-yards which are in use on a few general farms;
- deep litter, usually with a raised perforated floor incorporating perches.

Aviaries

In the late 1970s aviaries were developed from the get-away cage when Elson (1989) and colleagues in the UK designed a system which enabled hens to make better use of the volume of the building than is possible with deep litter. Several tiers of perforated platforms were built into the system, interconnected by ladders with each other and the littered floor. The platforms were constructed of wire or plastic mesh, or wooden slats; feed, water and nestboxes were provided at all levels. Stocking density varied from about 15 to 20 birds/m^2 of the ground floor area, depending on the number of tiers of platforms provided.

Detailed studies in The Netherlands during the 1980s led to the development of a type of aviary called the tiered wire floor (TWF) system for laying hens (Ehlhardt *et al.*, 1989; Blokhuis and Metz, 1995). In this system the birds had access to a littered floor from three tiers of wire platforms. Feed was available on the two lower platforms and water on all three. Perches were mounted over the top platform. Manure belts ran under the wire platforms to allow the manure to be removed. Tiered nestboxes were provided between the platforms. Thus the hens had access to scratching, feeding, drinking, nesting and resting areas. Stocking density was about 20 birds/m^2.

Soon afterwards several types of aviary were also developed in other countries especially Germany (Wegner, 1986; Rauch, 1991), The Netherlands (Ehlhardt *et al.*, 1989; van Niekerk and Ehlhardt, 1995), Switzerland (Oester, 1986) and Sweden (Hultgren, 1989; Tauson *et al.*, 1992; Abrahamsson and Tauson, 1995; Gunnarsson *et al.*, 1995). In many of these versions, manure belts or scrapers have been installed under the perforated platforms, so that birds living in the lower areas are clean, and a better environment can be maintained in the building by regular manure removal.

These principles have recently been incorporated into a new approach, the *portal aviary* (see Fig. 9.2). This improved design was developed in The Netherlands and is now in commercial use in several European countries. The

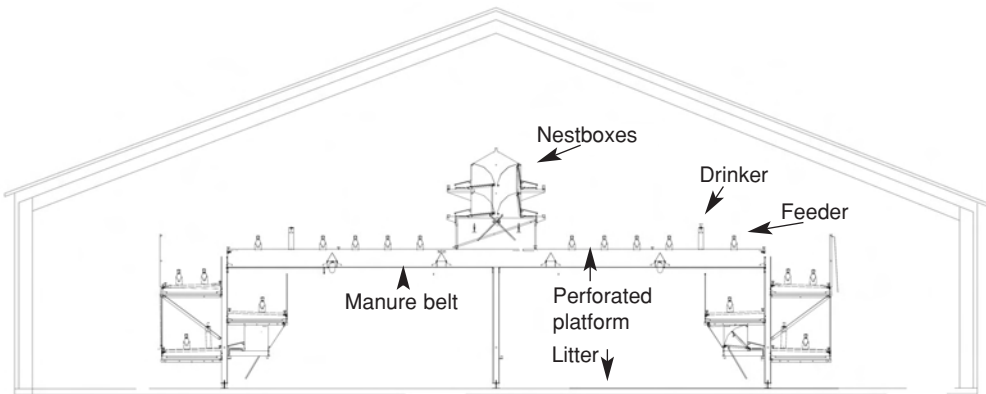

Fig. 9.2. Multi-tier portal aviary for laying hens.

whole of the house floor is littered, and fairly narrow stepped perforated platforms on each side lead up to a wide main overhead perforated platform under which operators can walk (see Fig. 9.2). All platforms have manure belts under them to remove droppings and prevent them falling on to lower levels. Operators can also walk on the upper platform to which access is gained by steps at the end of the house. This innovative design provides a good environment and allows hens ready access to all areas of activity. The system meets the requirements of the Directive at up to about 18 hens/m^2 of house floor area; stocking density on the usable area, including all platforms, is under 9 hens/m^2.

Percheries

The perchery system was conceived in Scotland in the 1980s (Michie and Wilson, 1984) and studied also in Germany (Rauch, 1991). It consisted of several tiers of perches mounted on an A frame and had narrow slatted platforms at the top with feeders and drinkers at most levels. Litter was provided at floor level and the system was stocked at 17 hens/m^2. Subsequently the Gleadthorpe perchery was developed and tested in England (Alvey, 1989). In this version, slatted platforms were eliminated, and care was taken to arrange perches to give easy access to nestboxes at all levels and to minimize manurial contamination of birds at lower levels. Feed and water were provided at all levels, and litter on the ground floor level only. It was stocked at up to 20 hens/m^2.

Multi-level percheries are not easy to manage, tend to have some hens contaminated with droppings at lower levels and often have a high proportion of hens with broken bones (Gregory *et al*., 1991). The latter may be ameliorated to some extent by ensuring that the perches are not too far apart and that hens do not jump at too steep an angle (Scott *et al*., 1997). However, it is very difficult to design multi-level percheries to prevent droppings falling on hens below.

The most successful perchery/barn system, which is easy to manage and is now in widespread use in the UK, is the single-level, part-litter (usually about one-third), part-raised perforated floor (usually about two-thirds with a manure collection pit under it). The perches are incorporated into the perforated floor, which has been accepted by most authorities as meeting perch requirements. This system is easier to manage than multi-level percheries and there is no problem with manure

falling from one level to another. It seems to fit the demands of the EU Directive well but is not necessarily immune from broken bone problems (especially keel bones). It has traditionally been stocked at just under 12 hens/m^2, but this has been reduced to 9 hens/m^2 in houses on new establishments and for all houses with this system from 2012.

Deep litter

The traditional deep-litter system was a single level with litter over most of the floor surface. It allowed a moderate stocking density of about 7 birds/m^2, which made litter management difficult in winter and house temperature difficult to maintain in cold weather. Where perches were used they were generally mounted on frames frequently moved about over the litter to spread the manure. Nestboxes could be along the side walls but this tended to encourage floor eggs to be laid under them; they were generally better sited back-to-back in the centre of the house, preferably over a raised platform. The traditional deep-litter system cannot meet the requirements of the EU Directive (i.e. perches cannot be mounted over litter) so it will be banned in the future; no new installations can now be made and existing ones cannot be used after 2006. However, deep litter in combination with raised perforated platforms (in or over which perches are provided) remains acceptable and is generally described as a perchery/barn system.

Outdoor Systems

Free-range systems provide hens with access outside and include fixed houses with outdoor pens for ranging and foraging, small houses frequently moved over the land providing sleeping accommodation, shelter and nestboxes, and carefully constructed fully furnished mobile houses that can be occasionally moved. Pasture management is important to control parasitic infestation, and shelter and shade should be provided outside to encourage hens to range. Fencing should be sound, and preferably electrified, to provide protection against predators. Housing for free-range systems can include any of those described above except conventional and enriched cages.

DESIGN AND MANAGEMENT OF ALTERNATIVE SYSTEMS TO CAGES

Design and management are interactive, and excellence in both is required to achieve economic performance and good welfare. Layout of equipment within pens is important, especially where high densities occur, and researchers and designers have been able to improve access to furniture by careful layout and design. Water is best provided over raised platforms, where installed, rather than over litter, especially where manure is regularly removed by conveyors. Perforated platforms can be kept clean, especially if suitable materials (e.g. plastic mesh) are used.

The material and design of nestboxes have important influences on the degree of use by birds and consequently the proportion of floor (and dirty and broken) eggs. Nestboxes are best closed at night to keep them clean by preventing hens from sleeping there. Rearing in a non-cage system, preferably with access

to raised perches, and early removal of eggs laid on the floor, are also important management factors.

Litter management can be difficult. In hot dry conditions, dust can be a problem and dust levels are generally much higher than in cages. In cold humid conditions it is difficult to avoid wet sticky litter developing with areas of hard 'capping' especially with low stocking densities, poor insulation or ventilation or a combination of these factors. High ammonia emissions can also be a problem. A good depth of a suitable absorbent material, e.g. wood shavings or chopped straw, is required. If possible it is best to ensure the litter is actively biodegrading faecal matter and is dry and friable before cold humid weather occurs and a scattering of grain on the litter will encourage the hens to move and mix it. If 'caking' occurs it may become necessary to turn the litter and remove wet or 'caked' patches.

External parasites, especially red mite, are often a problem in non-cage systems. Thorough cleaning and disinfestation procedures are recommended after depopulation with a chemical that achieves effective eradication of the parasites. Particular attention should be paid to small cracks and crevices, e.g. small gaps between timbers or plastic materials that can harbour the mites or their eggs while the house is depopulated; otherwise mites will re-emerge as soon as the new flock is housed. Care should be taken to ensure that infested birds do not arrive from the rearing farm. If infestations occur during the laying period, areas that harbour mites must be treated with suitable material; this is best done in the evening when mites move into more open spaces, since they migrate on to the birds to feed at night.

Another problem that frequently occurs in alternative systems is feather and injurious pecking, which frequently leads to cannibalism and mortality. The main methods of control are the avoidance of high or uneven light intensity and beak trimming. The latter can be painful at and following the time of the operation. The operation must be done at a young age (under 10 days). Authorities in several countries have either banned beak trimming or are planning to do so. In the UK this will take place at the end of 2010. It will make alternative systems to cages very difficult to manage and suffering and mortality levels will almost certainly increase unless satisfactory alternative methods of controlling cannibalism can be found.

WELFARE OF HENS IN VARIOUS SYSTEMS

Hens in non-cage systems generally have more space and greater freedom than hens in laying cages. This is often considered a welfare benefit. However, various risks that may reduce welfare, which are lower or absent in cages, do occur in alternative systems. The greatest is probably that of injurious pecking leading to body wounds, cannibalism and, sometimes, severe mortality. Currently pullet chicks destined for alternative systems have to suffer partial beak amputation.

In the UK, the Farm Animal Welfare Council (FAWC) believes that animal welfare should be considered with reference to its 'Five Freedoms' (FAWC, 1997). These were used to assess bird welfare, and to make recommendations for improvements in various aspects of egg production systems and their management in FAWC's report on the welfare of laying hens (FAWC, 1997). FAWC also carried out a welfare assessment of the pros and cons of conventional laying cages. Numerically the advantages exceeded the disadvantages by seven to five.

It has been claimed that cages cannot meet one of the five freedoms, i.e. freedom to express normal behaviour. However, three of the other five freedoms are compromised to varying degrees in alternative systems, i.e. freedom from discomfort, freedom from pain, injury and disease, and freedom from fear and distress. Thus, on balance, alternative systems seem unlikely to satisfy the five freedoms any better than cages. Therefore, banning cages might not be expected to give an overall improvement in bird welfare. A good case can be made for studying and analysing various systems of egg production in terms of how well they meet, or could be adjusted to meet, the five freedoms. This could help policy makers to reach better decisions when formulating directives and regulations.

REFERENCES

Abrahamsson, P. (1996) Furnished cages and aviaries for laying hens: effects on production, health and use of facilities. *Report 234*, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Abrahamsson, P. and Tauson, R. (1995) Aviary systems and conventional cages for laying hens: effect on production, egg quality, health and bird location in three hybrids. *Acta Agriculturae Scandinavica* 45, 191–203.

Abrahamsson, P., Tauson, R. and Appleby, M.C. (1995) Performance of four hybrids of laying hens in modified and conventional cages. *Acta Agriculturae Scandinavica* 45, 286–296.

Alvey, D.M. (1989) Evaluation of two perchery designs for egg production. *British Poultry Science* 30, 960.

Appleby, M.C. (1993) The Edinburgh system for laying hens. In: *Proceedings of Symposium on Modified Cages for Laying Hens.* UFAW, Potters Bar, UK, pp. 35–39.

Appleby, M.C., Walker, A.W., Nicol, C.J., Lindberg, A.C., Freire, R., Hughes, B.O. and Elson, H.A. (2002) Development of furnished cages for laying hens. *British Poultry Science* 43, 489–500.

BEIC (2002) *The British Egg Industry Council Code of Practice for Lion Eggs,* 4th version. BEIC, London.

Blokhuis, H.J. and Metz, J.H.M. (1995) Aviary housing for laying hens. *Spelderholt Publication No. 641*. ID-DLO, Lelystad, The Netherlands.

Blokhuis, H.J., Bessei, W., Elson, A., Faure, J.M., van Houwelingen, P., Keeling, L., Groot Koerkamp, P.W.G. and Simonsen, H. (1997) Report on the welfare of laying hens. In: Koene, P. and Blokhuis, H.J. (eds) *Proceedings of the 5th European Symposium of Poultry Welfare*. WPSA, Wageningen, The Netherlands, pp. 171–173.

Drakley, C., Elson, H.A. and Walker, A.W. (2002) Production efficiency of laying hens at four stocking densities in furnished cages of two heights. *Archiv für Geflugelkunde*. Verlag Eugen Ulmer, Stuttgart, Germany, p. 37.

Ehlhardt, D.A., Donkers, A.M.J., Hiskemuller, W. and Haartsen, P.I. (1989) Efficiency of the tiered wire floor (TWF) aviary as a housing system for laying hens, compared to cages. *Food and Water Use*. Dodds, Rotterdam, The Netherlands, pp. 1015–1019.

Elson, A. (2001) Why put popholes in laying cages? *ADAS Poultry Progress*, pp. 3–5.

Elson, A. (2002a) Deepening laying cages. *ADAS Poultry Progress*, p. 7.

Elson, A. (2002b) Claw shortener monitoring exercise: interim results. *Poultry World* 156 (11), 27.

Elson, A. (2003) Compliance of laying cages with new regulations. *ADAS Poultry Progress*, pp. 5–7.

Elson, H.A. (1976) New ideas on laying cage design: the 'get-away' cage. In: *Proceedings of the 5th European Poultry Conference.* WPSA, Malta, pp. 1030–1041.

Elson, H.A. (1985) The economics of poultry welfare. In: Wegner, R.M. (ed.) *Proceedings of the 2nd European Symposium on Poultry Welfare*. WPSA, Celle, Germany, pp. 244–253.

Elson, H.A. (1989) Improvement in alternative systems of egg production. In: Faure, J.M. and Mills, A.D. (eds) *Proceedings of the 3rd Symposium on Poultry Welfare*. WPSA, Tours, France, pp. 183–199.

Elson, H.A. (1990) Recent developments in laying cages designed to improve bird welfare. *World's Poultry Science Journal* 46, 34–37.

Elson, H.A. (1992) Evaluation of economic aspects of housing systems for layers. In: *Proceedings of the 19th World Poultry Congress.* WPSA, Amsterdam, The Netherlands, pp. 503–508.

Elson, H.A. (1993) The economics of modified enriched cages (MEC) compared to other systems of egg production. In: *Proceedings of a Seminar on Modified Laying Cage.* Universities Federation for Animal Welfare, Potters Bar, UK, pp. 91–93.

Elson, H.A. (1995) Intensive management and reproduction. In: Hunton, P. (ed.) *Poultry Production: World Animal Science Series C9*. Elsevier, Amsterdam, The Netherlands, pp. 390–403.

EU Directive (1988) Council Directive 88/166/EEC of 7 March 1988 laying down minimum standards for the protection of laying hens kept in battery cages. *Official Journal of the European Communities* No. L 74, 19.03.1988, pp. 83–87.

EU Directive (1999) Council Directive 99/74/EC of 19 July 1999 laying down minimum standards for the protection of laying hens. *Official Journal of the European Communities* No. L 203, 03.08.1999, pp. 53–57.

Faure, J.M. and Lageric, H. (1989) Space requirements of caged layers. In: *Alternative Improved Housing Systems for Poultry*. CEC Seminar, EUR 11711. CEC, Luxembourg, pp. 79–90.

FAWC (1997) *Report on the Welfare of Laying Hens. PB 3221*. MAFF, Tolworth, UK.

Fiks van Niekerk, T.G.C.M., Reuvekamp, B.F.J. and van Emous, R.A. (2002) Experiences with different models of enriched cages. *Archiv fur Geflugelkunde*. Verlag Eugen Ulmer, Stuttgart, Germany, pp. 60–61.

Gregory, N.G., Wilkins, L.J., Kestin, S.C., Belyavin, C.G. and Alvey, D.M. (1991) Effect of husbandry system on broken bones and bone strength in hens. *Veterinary Record* 128, 397–399.

Gunnarsson, S., Oden, K., Algers, B., Svedberg, J. and Keeling, L.J. (1995) Poultry health and behaviour in a tiered system for loose housed layers. *Report 35*, Swedish University of Agricultural Sciences, Skara, Sweden.

Haartsen, P.I. and Elson, H.A. (1989) Economics of alternative housing systems. In: *Alternative Improved Housing Systems for Poultry.* CEC Seminar, EUR. 11711. CEC, Luxembourg, pp. 143–150.

Hultgren, J. (1989) Evaluation of a Swedish aviary system for laying hens. In: Faure, J.M. and Mills, A.D. (eds) *Proceedings of the 3rd European Symposium on Poultry Welfare.* WPSA, Tours, France, pp. 233–235.

McBride, G. (1970) The social control of behaviour in fowls. In: Freeman, B.M. and Gordon, R.F. (eds) *Aspects of Poultry Behaviour.* British Poultry Science, Edinburgh, UK, pp. 3–13.

Michie, W. and Wilson, C.W. (1984) The perchery system of housing commercial layers. *World's Poultry Science Journal* 40, 179.

Oester, H. (1986) Systemes de detention recents pour pondeuses en Suisse. In: Larbier, M. (ed.) *Proceedings of the 7th European Poultry Conference.* WPSA, Paris, France, pp. 1077–1081.

Rauch, H.W. (1991) Neue Haltungsformen fur Legehennen. *Land Tecknik* 46, 232–234.

Rauch, H.W. (1993) Results and experiences with laying hens in get-away cages. In: *Proceedings of a Seminar on Modified Laying Cages*. UFAW, Potters Bar, UK, pp. 63–74.

RSPCA (2002) *Freedom Food Ltd: Welfare Standards for Laying Hens and Pullets.* RSPCA, Horsham, UK.

Scott, G.B., Lambe, N.R. and Hitchcock, D. (1997) Ability of laying hens to negotiate horizontal perches at different heights, separated by different angles. *British Poultry Science* 38, 48–54.

Tauson, R. (1986) Avoiding excessive growth of claws in caged laying hens. *Acta Agriculturae Scandinavica* 36, 95–106.

Tauson, R. and Holm, K.-E. (2001) First furnished small group cages for laying hens in evaluation program on commercial farms in Sweden. In: Oester, H. and Wyss, C. (eds) *Proceedings of the 6th European Symposium on Poultry Welfare*. WPSA, Zollikofen, Switzerland, pp. 26–32.

Tauson, R., Jansson, L. and Abrahamsson, P. (1992) Studies on alternative keeping systems for laying hens in Sweden at the Department of Animal Nutrition and Management. *Report 209*, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Tauson, R., Holm, K.-E. and Wall, H. (2002) Experiences from various furnished cage models in Sweden. *Archiv fur Geflugelkunde*. Verlag E Ulmer, Stuttgart, Germany, p. 37.

van Horne, P.L.M. (1996) Production and economic results of commercial flocks with white layers in aviary systems and battery cages. *British Poultry Science* 37, 255–261.

van Niekerk, T.C.G.M. and Ehlhardt, D.A. (1995) Zootechnics. In: Blokhuis, H.J. and Metz, J.H.M. (eds) *Aviary Housing for Laying Hens. Spelderholt Publication 641.* ID-DLO, Lelystad, The Netherlands, pp. 43–57.

van Niekerk, T.C.G.M. and Reuvekamp, B.F.J. (1995) Improving the welfare of laying hens in cages. *World Poultry* 11, 38–41.

Walker, A., Barkley, G. and Elson, A. (2003) Welfare and the egg industry: from beak trimming to furnished cages. In: *BEIC/NFU National Egg Conference*, pp. 18–21.

Wegner, R.M. (1986) Alternative systeme fur legehennen untersuchungen in Europa. In: Larbier, M. (ed.) *Proceedings of the 7th European Poultry Conference.* WPSA, Paris, France, pp. 1064–1076.

Wegner, R.M. (1990) Experience with the get-away cage system. *World's Poultry Science Journal* 46, 41–47.

WOFAR (2002) *The Welfare of Farmed Animals (England) (Amendment) Regulations 2002. SI 2002 No. 1646*. The Stationery Office, London, UK.

CHAPTER 10
Stress and the welfare of laying hens

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ABSTRACT

Stress occurs when an animal experiences any situation that alters normal body functions. Thus, when a situation endangers the health and well-being of an animal, the animal may experience distress. Distress, according to the United States Department of Agriculture (USDA, 2000), is 'a state in which an animal cannot escape from or adapt to external stressors or conditions it experiences, resulting in negative effects on its well-being'. It is clear that stress and animal welfare should not be examined separately.

There have been numerous reviews of stress and welfare in domestic fowl, especially juvenile birds, as separate subjects (Frankel, 1970; Freeman, 1971, 1976, 1985; Siegel, 1971, 1980, 1985, 1995; Maxwell, 1993; Jones, 1996; Downing and Bryden, 1999). However, stress and welfare have not been considered collectively. Welfare has been studied primarily using behavioural models, while stress studies have used physiological parameters. In order to properly review these subjects in combination, there must be a method for establishing a connection between the two types of research. The work of Puvadolpirod and Thaxton (2000a,b,c,d) and Thaxton and Puvadolpirod (2000) describing a model of stress in broilers will be used to establish this connection when and where appropriate. Therefore, the purpose of this chapter is to review pertinent research literature that describes stress and distress in laying hens.

STRESS AND DISTRESS RESPONSES

Stress and distress responses in laying hens can be assigned to five categories. These are: morphology, endocrine and blood metabolites, digestion and metabolism, immunity, and reproduction. Stress and distress responses caused by environmental, management and behavioural factors will be discussed and categorized into these five categories.

Morphological Changes

Body weight has been monitored as a response of hens to exposures to elevated temperatures. Results are not consistent. In two separate studies, hens acclimatized

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to thermoneutral conditions (15–26°C) were moved to a heated environment. During the first few weeks after the move, no changes in body weight occurred (Hester *et al.*, 1996a; Scheideler *et al.*, 2001). However, in other studies, loss in body weight occurred over the next several months in hens reared in hot climatic conditions (Zulovich and DeShazer, 1987; Samara *et al.*, 1996; Abdel-Rahman, 2000; Garces *et al.*, 2001). Hens maintained in a thermoneutral environment and exposed to daily cycles of 15.6–35°C did not experience a change in body weight over an 8-week period (Deaton *et al.*, 1981a,b). Lighting schedule effects on body weight were also observed in hens maintained in a heated environment. Their body weight increased when exposed to darkness daily for 2 h, compared with sister hens maintained on a conventional lighting schedule (Sahin and Kucuk, 2001; Ertas and Sahin, 2002).

General body condition, including body weight and appearance, was improved in hens moved from conventional cages to a furnished caging system. Such a system provided scratch poles, perches, dust baths and rollaway nests, all of which have been shown to be necessary to ensure the welfare of laying hens (Appleby, 1998; Maria *et al.*, 2001; Appleby *et al.*, 2002). Hen density (i.e. number of hens per unit of floor space) also influences body weight in laying hens. Specifically, as hen density was increased, body weight generally decreased (Iscan *et al.*, 1998).

Livability of laying hens is influenced by environment. Exposure to both hot and cold extremes resulted in a higher mortality rate (Uneo and Komiyama, 1987). Additionally, in hens acclimatized to thermoneutral temperatures, short episodes of heat or cold increased mortality (Uneo and Komiyama, 1987; Hester *et al.*, 1996a; Sahin and Kucuk, 2001; Ertas and Sahin, 2002). Livability of hens in floor pens compared to those in cages or in free-range environments is a debatable issue. Adams and Craig (1985) reviewed literature from 1971 to 1983 and concluded that caged hens exhibited greater levels of mortality than hens on floor conditions. Craig *et al.* (1986) showed that hens at high density in cages experienced greater mortality than hens on the floor and those at moderate and low cage densities. Moinard *et al.* (1998) agreed with this conclusion; however, Muir (1996) and Abrahamsson and Tauson (1997, 1998) reported that hen density did not affect the mortality rate of hens. Mou and Katle (1990) found no difference in mortality in hens on the floor versus hens in cages. Hafez *et al.* (2001) studied livability of free-ranging hens and those in a perchery. They reported that total mortality of free-ranging hens after 1 year was 16%, whereas it was 5.5% for hens in a perchery. Engstrom *et al.* (1993) showed that cannibalism was the major cause of mortality in floor-reared hens.

Cage design appears to play a major role in the mortality of hens in cages. Anderson and Adams (1991) reported that cage front type (vertical versus horizontal) did not affect mortality levels in hens. Moinard *et al.* (1998) showed that hens in tall cages experienced more mortality than hens in low cages. Furnished cage systems, compared with conventional cage systems, are reported to decrease or not affect mortality rates (Abrahamsson and Tauson, 1997, 1998; Maria *et al.*, 2001). However, Abrahamsson *et al.* (1996) reported that when a furnished system was fitted with getaway cages, mortality rate was greater than that in a furnished system without getaway cages. These authors concluded that increased cannibalism was the major cause of death in the getaway system. Several reports suggest that beak-trimming reduced cannibalism (Craig and Lee, 1989, 1990; Lee and Craig, 1991; Cunningham, 1992; Craig and Muir, 1996; Bell *et al.*, 1998).

Various stressors are known to cause changes in several internal organs of laying hens. Hypertrophy of the adrenal glands occurred when White Leghorn hens were maintained at high density in floor pens (Siegel, 1959). Keutgen *et al*. (1999) demonstrated that acute heating episodes caused hypertrophy of liver. They diagnosed the condition as fatty liver syndrome. Abdel-Rahman (2000) found that hens maintained in a high-temperature environment experienced decreased weight of liver, heart and ovary as time in lay increased.

Skeletal integrity, influenced by stress in laying hens, has been studied extensively. The initial report showed that when caged hens were given daily access to floor pens, wing breakage terminated (Meyer and Sunde, 1974). Then, in 1986, conflicting results were presented by Harms and Arafa (1986). Several reports demonstrate that hens maintained in floor pens possess stronger bones than hens in cages (Taylor and Hurnik, 1994; Newman and Leeson, 1998; Leyendecker *et al*., 2002). However, bone ash and bone calcium concentrations did not differ between hens maintained in cages and those on the floor (Chepete and Xin, 1999). Additionally, hens in a furnished cage system exhibited better bone integrity than hens in conventional cages (Wilson *et al*., 1972; Hughes and Appleby, 1989; Knowles and Broom, 1990; Engstrom *et al*., 1993; Tauson and Abrahamsson, 1996; Abrahamsson and Tauson, 1997, 1998). Also, Moinard *et al*. (1998) reported that hens in tall cages possessed stronger bones than hens in shorter cages.

The feet of hens reared in cages, compared to those on the floor, always showed abnormalities. Primary among these are increased claw length (Appleby *et al*., 1993; Taylor and Hurnik, 1994; Abrahamsson and Tauson, 1997) and toe hyperkeratosis (Engstrom *et al*., 1993; Abrahamsson and Tauson, 1997, 1998). Alvey and Tucker (1994) reported that cage floors constructed of a finer mesh wire reduced the incidence of toe hyperkeratosis.

The keels of hens in cages were more often damaged than the keels of floor-reared hens (Appleby *et al*., 1993; Abrahamsson and Tauson, 1997). Several reports showed that the incidence of all body injuries was reduced when hens were maintained in furnished cages (Abrahamsson and Tauson, 1997; Moinard *et al*., 1998; Appleby *et al*., 2002; Cloutier and Newberry, 2002).

Plumage condition is affected by housing conditions. The literature is clear that hens maintained in floor pens have less feather damage than hens maintained in cages (Craig *et al*., 1986; Taylor and Hurnik, 1994; Huber-Eicher and Sebo, 2001; McAdie and Keeling, 2002). Additionally, it has been demonstrated that the greater the density of hens in cages, the greater the degree of feather damage (Craig *et al*., 1986; Appleby *et al*., 1993, 2002; Taylor and Hurnik, 1994). Hens in furnished cages are reported to possess better feather quality than hens in conventional caging systems (Appleby *et al*., 1993; Engstrom *et al*., 1993; Tauson and Abrahamsson, 1996; El-Lethey *et al*., 2000; Maria *et al*., 2001). Tauson and Abrahamsson (1996) and El-Lethey *et al*. (2000) concluded that hens with perfect plumage were generally less stressed than hens with damaged feathers. Hens with elevated feed troughs were shown to have better plumage than sister hens eating out of conventional troughs (Freire *et al*., 1999). Finally, Moinard *et al*. (1998) studied cage height and concluded that height did not affect the plumage of laying hens.

Endocrine and Blood Metabolite Changes

Plasma corticosterone (CS), the putative stress hormone of fowl, has been studied in laying hens subjected to various stressors. Results are less than conclusive that blood CS is a stress response of laying hens. Craig *et al*. (1986) stated, 'Not only may corticoids fail to indicate the presence of stressful situations, but they also may be misleading by indicating that stressful conditions prevail when they do not'. The research literature bears out this concern.

Perek and Eckstein (1959) showed that adrenal ascorbic acid levels were decreased in laying hens that received exogenous adrenocorticotropin (ACTH). This is indirect evidence that CS is a stress response of laying hens. Wolford and Ringer (1962) reported that ACTH, cold and handling caused adrenal cholesterol depletion. This too is indirect evidence that CS is a stress response of laying hens. Downing and Bryden (1999) demonstrated that acute episodes of heat caused increased plasma CS, and Hester *et al*. (1996b) demonstrated that acute episodes of cold, but not heat, elevated CS.

Several reports, however, suggest that caged hens maintain levels of plasma CS that do not differ from CS levels in floor-reared hens (Koelebeck and Cain, 1984). Others have reported higher CS levels in floor-reared hens than in caged hens (Edens *et al*., 1982; Craig and Craig, 1985; Craig *et al*., 1986). Mashaly *et al*. (1984) and Craig *et al*. (1986) showed that stocking density had a significant influence on CS levels. Conversely, Davis *et al*. (2000) showed that increasing hen density in cages did not cause elevations in blood CS, triiodothyronine and tetraiodothyronine. Litten and Cockrem (2001) and Downing and Bryden (1999) showed that handling the hens elevated plasma CS within 15 min, but that CS level returned to baseline within 12 h. Beuving *et al*. (1989) demonstrated that plasma CS increased in response to fear caused by tonic immobility. Fitko *et al*. (1993) confirmed this report and recorded transient increases in both plasma CS and adrenaline. Chen *et al*. (2002) showed that intermingling strange hens with resident hens resulted in elevated plasma CS and dopamine levels. Finally, Compton *et al*. (1980) declawed hens and found no effects on blood levels of CS, progesterone or estradiol.

Gross and Siegel (1983) proposed that elevation in circulating numbers of heterophils (H) concomitant with decreased circulating numbers of lymphocytes (L), i.e. increased H:L ratio, is the best indicator of stress in fowl. There is little doubt that in laying hens this proposal is correct.

Wolford and Ringer (1962) showed that hens given ACTH experienced an increase in H:L ratio. Exposures of hens to heat or cold (Wolford and Ringer, 1962; Hester *et al*., 1996c; Campo and Davila, 2002), fear induced by handling or tonic immobility (Wolford and Ringer, 1962; Beuving *et al*., 1989; Fitko *et al*., 1993), poor litter conditions (El-Lethey *et al*., 2000) and partitions on the ends of cages versus open-ended cages (Elston *et al*., 2000a,b) all elevated the H:L ratio. Hester *et al*. (1996c) showed that increased density of hens in cages resulted in an increased H:L ratio; however, Davis *et al*. (2000) reported conflicting results. Finally, Garcia-Davila and Campo (2001) found that light regimes of 24, 14 and 18.5 h/day did not affect the H:L ratios of hens.

Several blood metabolites in laying hens are affected by stress. Blood Ca^{2+} levels are decreased when hens are subjected to heated conditions (Sahota *et al*., 1993; Mahmoud *et al*., 1996; Abdel-Rahman, 2000). Additionally, Mahmoud *et al*.

(1996) showed that heat reduced the transport of Ca^{2+} from the duodenum into the bloodstream. When hens were reared in heated conditions and subjected to feed withdrawal and periods of darkness, increases in pH, pCO_2 and $pHCO_3$ were recorded (Ertas and Sahin, 2002). Heated hens experienced increased blood concentrations of glucose, blood urea nitrogen, uric acid, albumin, triglycerides, cholesterol, Ca^{2+}, P^+, Na^+, K^+, alkaline phosphatase and amylase, although concentrations of glutamic oxaloacetic transaminase and pyruvic transaminase did not increase (Sahin and Kucuk, 2001). Heated hens also experienced decreased levels of circulating haemoglobin (Abdel-Rahman, 2000).

Digestive and Metabolic Changes

The major digestive and metabolic parameters of feed intake and feed efficiency have been studied in laying hens subjected to stressful situations. When hens acclimatized within the thermoneutral zone were moved to heated conditions, they experienced decreased feed intake and feed efficiency (Warren and Schnepel, 1940; Miller and Sunde, 1975; de Andrade *et al*., 1977; Sykes and Fataftah, 1986; Njoku and Nwazota, 1989; Pierre, 1989; Otten *et al*., 1989; Samara *et al*., 1996; Balnave and Muheereza, 1998; Garces *et al*., 2001; Najibid and Al-Yousef, 2001; Scheideler *et al*., 2001; Ertas and Sahin, 2002). However, Deaton *et al*. (1981a,b) showed that hens exposed to a cyclic temperature regime (15.6–35°C) for 8 weeks did not differ in feed intake or feed efficiency from hens maintained at 21°C. Additionally, hens reared in a hot climate that were given a daily period of darkness exhibited better feed intake and digestibility than heated controls maintained on a continuous lighting scheme (Ertas and Sahin, 2002).

The role of hen density on feed consumption and efficiency is not clear. Increased density was shown to decrease feed consumption (Lee and Craig, 1991) and to decrease feed efficiency (Roush *et al*., 1984). However, others have shown that density had no effects on feed consumption and efficiency (Brake and Peebles, 1992; Iscan *et al*., 1998).

Hens maintained in cages exhibited decreased feed consumption compared with floor-reared hens (Suto *et al*., 1994). Hens in furnished cage systems consumed more feed than hens in conventional cages (Appleby *et al*., 2002). However, another report showed that hens in furnished cages had a feed efficiency similar to hens in conventional cages (Tauson and Abrahamsson, 1996).

Aspects of cage design including area, configuration of feeders, shape and angles of fronts, and floor construction are known to affect both feed consumption and efficiency (Anderson and Adams, 1991; Dun *et al*., 1991; Sherwin *et al*., 1993; Tanaka *et al*., 1993; Barnett *et al*., 1997; Appleby, 1998; Appleby *et al*., 2002). Additionally, a getaway cage system did not seem to affect feed consumption of hens when compared to hens in conventional cages (Rauch and Sherwin, 1994).

Immune System Changes

A limited amount of research has been published on the effects of stressors on the immune system of laying hens. Hester *et al*. (1996c) showed that when hens

reared in a thermoneutral environment were exposed to acute heating or cold episodes they experienced immunosuppression, indicated by reduced circulating levels of anti-sheep erythrocyte antibodies. Puthpongsiriporn *et al*. (2001) subjected acclimatized hens to heating episodes and found that lymphocyte proliferation responses *in vitro* to the mitogen concanavalin A and a lipopolysaccharide fraction from *Salmonella typhimurium* were suppressed. Erhard *et al*. (2000) studied humoral immune responsiveness in hens reared in floor pens and cages. Antibody titres to human IgG were lowest in floor-reared hens. Additionally, these researchers assessed maternal immunity in the hens by determining total IgY levels in egg yolks. Yolks from floor-reared hens contained less IgY than yolks from caged hens. Circulating antibody levels to both sheep erythrocytes and tetanus toxoid antigens were elevated in hens in floor pens with straw litter compared with hens without straw (El-Lethey *et al*., 2000).

Schaar (1996) surveyed laying hens in Germany for incidence of *Salmonella enteriditis*. Faecal samples on a flock basis were collected and cultured for *S. enteriditis*. Results show that 47.5% of flocks of floor-reared hens possessed *S. enteriditis*, while 35% of caged flocks harboured this bacterium.

Reproductive Changes

The role of stress on reproduction in hens has been studied extensively. Reproduction is not universally accepted as a valid indicator of either stress status or the general welfare of hens. However, various reproductive functions are affected by climate, management and behavioural factors known to cause both stress and distress changes in hens.

Hens exposed to heated environments experience several reproductive effects. Several reports show that both acute and chronic heating episodes decreased hen-day egg production (HDP) (Pierre, 1989; Sahota *et al*., 1993; Hester *et al*., 1996a; Samara *et al*., 1996; Kita *et al*., 1997; Scheideler *et al*., 2001). Conversely, several other reports show that heating episodes had no effect on HDP (Selmi and Horst, 1983, 1984; Abdel-Rahman, 2000; Ertas and Sahin, 2002). Hester *et al*. (1996a) demonstrated that exposure to cold also decreased HDP. Heat decreased egg weight (Selmi and Horst, 1983, 1984; Pierre, 1989; Samara *et al*., 1996), specific gravity (Pierre, 1989; Samara *et al*., 1996; Ertas and Sahin, 2002) and several eggshell parameters, including weight (Kita *et al*., 1997; Sahin and Kucuk, 2001), strength (Kita *et al*., 1997) and thickness (Sahota *et al*., 1993; Samara *et al*., 1996; Ertas and Sahin, 2002). Heating episodes did not affect the period of time from one ovulation to the next, nor time from one oviposition to the next (Samara *et al*., 1996).

Crowding is known to affect egg production. Pearl and Surface (1904) were the first to report that crowding of floor-reared hens decreased HDP. Siegel (1959) confirmed this finding and described crowding as the first stressor identified in laying hens. Many reports indicate that crowding hens in cages affects HDP (Marks *et al*., 1970; Dorminey and Arscott, 1971; Bell, 1972; Hill and Binns, 1973; Hill, 1977; Robinson, 1979; Martin and Carter, 1980; Martin *et al*., 1980; Muir *et al*., 1980; Cunningham, 1981, 1982a,b; Cunningham and Ostrander, 1981; Carey, 1982; Ouart and Adams, 1982; Adams, 1983; Fairfull *et al*., 1983; Adams and Craig, 1985; Anderson and Adams, 1991; Vanskike and Adams, 1993; Bell *et al*., 1998).

Generally, the HDP of hens in furnished cage systems is reported not to differ from that of hens in conventional cages (Appleby *et al*., 1993; Tauson and Abrahamsson, 1996; Abrahamsson and Tauson, 1997, 1998; Maria *et al*., 2001; Appleby *et al*., 2002). However, hens in furnished cages are reported to lay more abnormal eggs (Tauson and Abrahamsson, 1996; Appleby *et al*., 2002), produce increased numbers of cracked eggs (Appleby *et al*., 1993; Abrahamsson *et al*., 1996; Abrahamsson and Tauson, 1997, 1998), with decreased shell strength (Leyendecker *et al*., 2002), and fewer dirty eggs (Appleby *et al*., 1993; Abrahamsson and Tauson, 1997, 1998). Additionally, Wall and Tauson (2002) reported that when egg-saver wires were added to furnished cages the numbers of cracked eggs were greatly reduced.

STRESS CONTROL MEASURES

Measures to lessen stress have been aimed primarily at reducing the effects caused by exposures to elevated temperatures. Measures to improve the welfare of hens have primarily been alterations in the design of caging systems.

Dietary additions of vitamins A, C, E and B_3 have been shown to reduce stress effects in heated hens (Njoku and Nwazota, 1989; Oruwari *et al*., 1995; Puthpongsiriporn *et al*., 2001; Scheideler *et al*., 2001; Campo and Davila, 2002; Lin *et al*., 2002). However, dietary treatments with zinc methionine and sodium bicarbonate did not reduce the effects of heat on egg production (Kita *et al*., 1997; Balnave and Muheereza, 1998). Periods of intermittent light and daily periods of complete darkness were shown to improve egg production in heated hens (Balnave and Muheereza, 1998; Ertas and Sahin, 2002). It was also found that sprinkler systems (Chepete and Xin, 1999; Ikeguchi and Xin, 2001) and water-cooled roosts (Otten *et al*., 1989; Muiruri and Harrison, 1991) reduced stress effects caused by heat.

The systems of management for laying hens include free-range, floor pens and various caging systems. For each of these, there is published literature suggesting that it is best for the general welfare of laying hens. However, most of the research literature favours the furnished cage system for general welfare of laying hens (Appleby and Hughes, 1991, 1995; Baxter, 1994; Rauch and Sherwin, 1994; Ekstrand and Keeling, 1995; Hoffmann and Anderson, 1996; Tauson and Abrahamsson, 1996; Tengvall, 1996; Abrahamsson and Tauson, 1997; van der Weghe and van der Weghe, 2000; Appleby, 2001; Duncan, 2001; Maria *et al*., 2001; Appleby *et al*., 2002).

CONCLUSIONS

Laying hens experience both stress and distress responses when subjected to various environmental, management and behavioural stressors. Avian research scientists generally accept distress responses as an integral part of the recognition process of an imposing stressor. However, behaviourists have described distress responses independent of physiological stress. This chapter has attempted to present the various stress and distress changes as adaptive responses in stressed laying hens.

Stress and distress changes in laying hens are generally the same as those of broilers, with the exception of reproductive alterations. As expected, the temporal and kinetic patterns of these responses vary between layers and broilers. The H:L ratio is the most predictable stress and distress response in layers. Many avian physiologists contend that this parameter is also the best stress indicator in broilers. However, Thaxton and Puvadolpirod (2000) proposed a method to quantify stress responses in chickens and reported that CS was the most sensitive stress response in broilers.

One can argue that reproductive alterations are not physiological stress or distress responses. Alternatively, arguments that reproductive changes are a part of physiological stress have been put forth. It is clear, however, that more research is required to complete the physiological profile of stress and distress responses for all ages, sexes and types of domestic fowl.

REFERENCES

Abdel-Rahman, A. (2000) Evaluation of egg production performance of the naked neck chicken (Sharkasi) under long-term heat stress conditions. *Assuit Journal of Agricultural Sciences* 31, 269–289.

Abrahamsson, P. and Tauson, R. (1997) Effect of group size on performance, health and birds' use of facilities in furnished cages for laying hens. *Acta Agriculturae Scandinavica* 47, 254–260.

Abrahamsson, P. and Tauson, R. (1998) Performance and egg quality of laying hens in an aviary system. *Journal of Applied Poultry Research* 7, 225–232.

Abrahamsson, P., Tauson, R. and Appleby, M.C. (1996) Behaviour, health and integument of four hybrids of laying hens in modified and conventional cages. *British Poultry Science* 37, 521–540.

Adams, A.W. (1983) Cage shape, type of cage partition and feed trough divider effects on performance of White Leghorn layers. In: *Proceedings of the 18th Midwestern Poultry Conference, Manhattan, KS, USA*, pp. 7–11.

Adams, A.W. and Craig, J.V. (1985) Effect of crowding and cage shape on productivity and profitability of caged layers: a survey. *Poultry Science* 64, 238–242.

Alvey, D.M. and Tucker, S.A. (1994) Effect of cage floor mesh size and wire thickness on the foot condition of laying hens. In: *Proceedings of the 9th European Poultry Conference, Glasgow,* pp. 280–281.

Anderson, K.E. and Adams, A.W. (1991) Effects of type of cage front and feed trough partitions on productivity and ingestive, agonistic and fearful behaviors of egg-type hens. *Poultry Science* 70, 770–775.

Appleby, M.C. (1998) The Edinburgh modified cage: effects of group size and space allowance. *Journal of Applied Poultry Research* 7, 152–161.

Appleby, M.C. (2001) Housing for laying hens in North America and Europe. *Biotechnology in Animal Husbandry* 17, 33–36.

Appleby, M.C. and Hughes, B.O. (1991) Welfare of laying hens in cages and alternative systems: environmental, physical and behavioural aspects. *World's Poultry Science Journal* 47, 109–128.

Appleby, M.C. and Hughes, B.O. (1995) The Edinburgh modified cage for laying hens. *British Poultry Science* 35, 707–718.

Appleby, M.C., Smith, S.F. and Hughes, B.O. (1993) Nesting, dust bathing and perching by laying hens in cages: effects of design on behaviour and welfare. *British Poultry Science* 34, 835–847.

Appleby, M.C., Walker, A.W., Nicol, C.J., Lindberg, A., Freire, C.R., Hughes, B.O. and Elson, H.A. (2002) Development of furnished cages for laying hens. *British Poultry Science* 43, 489–500.

Balnave, D. and Muheereza, S.K. (1998) Intermittent lighting and dietary sodium bicarbonate supplementation for laying hens at high temperatures. *Australian Journal of Agricultural Rese*arch 49, 279–284.

Barnett, J.C., Glatz, P.C., Newman, E.A. and Cronin, G.M. (1997) Effects of modifying layer cages with solid sides on stress physiology, plumage, and pecking and bone strength of hens. *Australian Experimental Agriculture* 37, 11–18.

Baxter, M.R. (1994) The welfare problems of laying hens in battery cages. *Veterinary Record* 134, 614–619.

Bell, D. (1972) Reverse cage demonstrates striking income advantage. *Poultry Digest* 31, 326–328.

Bell, D.D., Adams, C.J. and Gvaryahu, G. (1998) Environment enrichment devices for caged laying hens. *Journal of Applied Poultry Research* 1, 19–26.

Beuving, G., Jones, R.B. and Blokhuis, H.J. (1989) Adrenocortical and heterophil/lymphocyte responses to challenge in hens showing short or long tonic immobility reactions. *British Poultry Science* 30, 175–184.

Brake, J.D. and Peebles, E.D. (1992) Laying hen performance as affected by diet and cage density. *Poultry Science* 71, 945–950.

Campo, J.L. and Davila, S.G. (2002) Influence of mating ratio and group size on indicators of fearfulness and stress of hens and cocks. *Poultry Science* 81, 1099–1103.

Carey, J.B. (1982) Effect of cage type and feeding level on laying performance and feeding behavior of several commercial strains of egg-type chicken. PhD dissertation, Kansas State University, Manhattan, Kansas, USA.

Chen, H.W., Singleton, P. and Muir, W.M. (2002) Social stress in laying hens: differential dopamine and corticosterone responses after intermingling different genetic strains of chickens. *Poultry Science* 81, 1265–1272.

Chepete, H.J. and Xin, R.H. (1999) Evaluation of intermittent partial surface wetting on heat stress relief of laying hens. In: *American Society of Agricultural Engineers-CSAE-SCGR International Meeting,* Toronto, Canada, pp. 18–21.

Cloutier, S. and Newberry, R.C. (2002) A note on aggression and cannibalism in laying hens following re-housing and re-grouping. *Applied Animal Behaviour Science* 76, 157–163.

Compton, M.M., Van Krey, H.P., Ruszler, P.C. and Gwazdauskas, F.C. (1980) The effects of claw removal on growth rate, gonadal steroids, and stress response in cage-reared pullets. *Poultry Science* 60, 2120–2126.

Craig, J.V. and Craig, J.A. (1985) Corticosteroid levels in White Leghorn hens as affected by handling, laying-house environment and genetic stock. *Poultry Science* 64, 809–816.

Craig, J.V. and Lee, H.-Y. (1989) Genetic stocks of White Leghorn-types different in relative productivity when beaks are intact versus trimmed. *Poultry Science* 6, 1720–1723.

Craig, J.V. and Lee, H.-Y. (1990) Beak trimming and genetic stock effects on behavior and mortality from cannibalism in White Leghorn-type pullets. *Applied Animal Behaviour Science* 25, 107–123.

Craig, J.V. and Muir, W.M. (1996) Group reflection for adaptation to multiple-hens cages: beak-related mortality, feathering and body weight responses. *Poultry Science* 75, 294–302.

Craig, J.V., Craig, J.A. and Vargas, J.V. (1986) Corticosteroids and other indicators of hens' well-being in four laying house environments. *Poultry Science* 65, 856–863.

Cunningham, D.L. (1981) The effects of social rank and cage shape on selected behavioral and performance traits of White Leghorn layers. *Poultry Science* 60, 2593–2598.

Cunningham, D.L. (1982a) Layer performance in deep and shallow cages: the importance of feed intake differences. *Poultry Science* 61, 1927–1929.

Cunningham, D.L. (1982b) Cage type and density effects on performance and economic factors of caged layers. *Poultry Science* 61, 1944–1949.

Cunningham, D.L. (1992) Beak-trimming effects on performance, behavior and welfare of chickens: a review. *Journal of Applied Poultry Research* 1, 129–134.

Cunningham, D.L. and Ostrander, C.E. (1981) An evaluation of layer performance in deep and shallow cages at different densities. *Poultry Science* 60, 2010–2016.

Davis, G.S., Anderson, K.E. and Carroll, A.S. (2000) The effects of long-term caging and molt of single comb White Leghorn hens. *Poultry Science* 79, 514–518.

de Andrade, A.N., Rogler, J.C., Featherstone, W.R. and Alliston, C.W. (1977) Interrelationships between diet and elevated temperatures (cyclic and constant) on egg production and shell quality. *Poultry Science* 56, 1178–1188.

Deaton, J., McNaughton, J.L. and Lott, B.D. (1981a) Effect of heat stress on laying hen acclimated to cyclic versus constant temperature. *Poultry Science* 61, 875–878.

Deaton, J.W., Reece, F.N., McNaughton, J.L. and Lott, B.D. (1981b) Effect of differing temperature cycles on egg shell quality and layer performance. *Poultry Science* 60, 733–737.

Dorminey, R.W. and Arscott, G.H. (1971) Effects of bird density, nutrient density and perches on the performance of caged White Leghorn layers. *Poultry Science* 50, 619–626.

Downing, J.A. and Bryden, W.L. (1999) *Stress, Hen Husbandry and Welfare: Literature Review of Stress in Poultry*. RIRDC/EIRDC, Barton, ACT, Australia.

Dun, P., Hughes, B.O., Howie, T.J., Michie, W., Shamash, E. and Wright, D. (1991) Cages for laying hens. *Farm Building Progress* 106, 25–27.

Duncan, I.J.H. (2001) The pros and cons of cages. *World's Poultry Science Journal* 57, 381–390.

Edens, F.W., Martin, G.A. and Carter, T.A. (1982) Stress responses of two layer stocks in five cage densities compared to floor birds. *Poultry Science* 61, 1456.

Ekstrand, C. and Keeling, L. (1995) Modified cages for laying hens. *Svensk Veterinartiding* 47, 261–267.

El-Lethey, H., Aerni, V., Jongi, T.W. and Wechsler, B. (2000) Stress and feather pecking in laying hens in relation to housing conditions. *British Poultry Science* 41, 22–28.

Elston, J.J., Beck, M.M., Kachman, S.D. and Scheideler, S.E. (2000a) Laying hen behaviour. 1. Effects of cage type and startle stimuli. *Poultry Science* 79, 471–476.

Elston, J.J., Beck, M.M., Alodan, M.A. and Vega-Murillo, V. (2000b) Laying hen behaviour. 2. Cage type preference and heterophil to lymphocyte ratio. *Poultry Science* 79, 477–482.

Engstrom, B., Schaller, G., Savory, C.J. and Hughes, B.O. (1993) Experimental studies on the health of laying hen in relation to housing systems. In: *Proceedings of the 4th European Symposium on Poultry Welfare, Bath, UK*, pp. 87–96.

Erhard, M.H., Özpinar, H., Bilal, T., Abbas, Y., Kutay, C., Eseceli, H. and

Stangassinger, M. (2000) The humoral immune response and the productivity of laying hens kept on the ground or in cages. *Alternatives to Laboratory Animals* 28, 699–705.

Ertas, O.N. and Sahin, K. (2002) Preventing heat stress with different feeding methods in laying hens. *Turkisg Veterinelikveltay Vancilik Dergisi* 26, 453–462.

Fairfull, R.W., Garwood, V.A., Spencer, J.L., Gave, R.S. and Lowe, P.C. (1983) The effects of geographical area, rearing method, caging density, and lymphoid leukosis infection on adult performance in egg stocks of chickens. *Poultry Science* 62, 2360–2370.

Fitko, R., Jakubowski, K., Zielinski, H. and Potrzuska, I. (1993) The level of corticosterone, adrenaline and noradrenaline and activity of blood neutrophils in chickens under an acute immobilization stress. *Medycyna Weterynaryjna* 49, 37–38.

Frankel, A.I. (1970) Neurohumoral control of the avian adrenal: a review. *World's Poultry Science Journal* 49, 869–921.

Freeman, B.M. (1971) Stress and the domestic fowl: a physiological appraisal. *World's Poultry Science Journal* 27, 663–666.

Freeman, B.M. (1976) Stress and the domestic fowl: a physiological re-appraisal. *World's Poultry Science Journal* 32, 249–256.

Freeman, B.M. (1985) Stress and the domestic fowl: physiological fact or fantasy? *World's Poultry Science Journal* 41, 45–51.

Freire, R., Walker, A. and Nicol, C.J. (1999) The relationship between trough height, feather cover and behaviour of laying hens in modified cages. *Applied Animal Behaviour Science* 63, 55–64.

Garces, A., Casey, N.H. and Horst, P. (2001) Productive performance of naked neck, frizzle and dwarf laying hens under various natural climates and two nutritional treatments. *South African Journal of Animal Science* 31, 174–180.

Garcia-Davila, S.C. and Campo, J.L. (2001) The genotype × photoperiod interaction for stress-related characters in laying hens. In: *IX Jornades sobre Producción Animal, Zaragoza, Spain*, pp. 81–83.

Gross, W.B. and Siegel, H.S. (1983) Evolution of the heterophil/lymphocyte ratio as a measure of stress in chickens. *Avian Diseases* 27, 972–979.

Hafez, H.M., Mazaheri, A., Prusas, C., Bohland, K., Poppel, M. and Schulze, D. (2001) Actual infectious diseases in laying flocks kept in alternative rearing systems. *Tierarztliche Praxis* 29, 168–174.

Harms, R.H. and Arafa, A.S. (1986) Changes in bone fragility in laying hens. *Poultry Science* 65, 1814–1815.

Hester, P.Y., Muir, W.M., Craig, J.V. and Albright, J.L. (1996a) Group selection for adaptation to multiple-hen cages: hematology and adrenal function. *Poultry Science* 75, 1295–1307.

Hester, P.Y., Muir, W.M., Craig, J.V. and Albright, J.L. (1996b) Group selection for adaptation to multiple-hen cages: production traits during heat and cold exposures. *Poultry Science* 75, 1308–1314.

Hester, P.Y., Muir, W.M. and Craig, J.V. (1986c) Group selection for adaptation to multiple-hen cages: humoral immune response. *Poultry Science* 75, 1315–1320.

Hill, A.T. (1977) The effects of space allowance and group size on egg production traits and profitability. *British Poultry Science* 18, 483–497.

Hill, A.T. and Binns, M.R. (1973) Effect of varying population density and size on laying performance. In: *IV European Poultry Conference, London*, pp. 609–609.

Hoffmann, R. and Anderson, H. (1996) *Welfare Economic Effects of a Prohibition on Keeping Laying Hens in Cages* (*Samhallsekonmisha Konsekvenserav ett*

burforbid for varphons). Rapport Sveriges Lantbruksuniversitet, Institutionen för ekonomi Lantbruksekonomi 96. Uppsala, Sweden.

Huber-Eicher, B. and Sebo, F. (2001) Reducing feather pecking when raising hen chicks in aviary systems. *Applied Animal Behaviour Science* 73, 59–68.

Hughes, B.O. and Appleby, M.C. (1989) Increases in bone strength in spent laying hens housed in modified cages with perches. *Veterinary Record* 124, 483–485.

Ikeguchi, A. and Xin, H. (2001) Field evaluation of a sprinkling system for cooling commercial laying hens. *Applied Engineering for Agriculture* 17, 217–221.

Iscan, K.M., Tekin, M.E. and Inal, S. (1998) The performance of laying hens housed at different cage densities. *Hayvancilik Arastirma Dergisi* 8, 111–114.

Jones, B.R. (1996) Fear and adaptability in poultry: insights, implications and imperatives. *World's Poultry Science Journal* 52, 130–172.

Keutgen, H., Worm, S. and Ueberschar, S. (1999) Pathologic changes in end-of-lay hens with regards to different housing systems. *Deutsche Tierarztliche Wochenschrift* 106, 127–133.

Kita, K., Hohmura, I. and Kumura, J. (1997) Influence of dietary zinc methionine supplementation on eggshell quality in hens under hot climate environment. *Japanese Poultry Science* 34, 21–26.

Knowles, T.G. and Broom, D.M. (1990) Limb bone strength and movement in laying hens from different housing systems. *Veterinary Record* 126, 354–356.

Koelebeck, K.W. and Cain, J.R. (1984) Performance behavior, plasma corticosterone, and economic returns of laying hens in several management alternatives. *Poultry Science* 63, 2123–2131.

Lee, H.-Y. and Craig, J.C. (1991) Beak trimming effects on behavior pattern, fearfulness, fathering and mortality among three stocks of White Leghorn pullets in cages and floor-reared. *Poultry Science* 70, 211–214.

Leyendecker, M., Hamann, H., Hartung, J., Glunder, G., Nogossek, N., Neumann, U., Kamphues, J. and Dish, O. (2002) Analysis of the eggshell stability and the bone strength of laying hens in three different housing systems. *Zuchtungskunde* 74, 144–155.

Lin, H., Wang, L.F., Song, J.L., Xie, Y.M. and Yang, Q.M. (2002) Effects of dietary supplemental levels of vitamin A on the egg production and immune responses of heat-stressed laying hens. *Poultry Science* 81, 458–465.

Litten, K.E. and Cockrem, J.F. (2001) Individual variation in corticosterone secretion in laying hens. *British Poultry Science* 42, 536–546.

Mahmoud, K.Z., Beck, M.M., Sheideler, S.E., Forman, M.F., Anderson, K.P. and Kachman, S.D. (1996) Acute high environmental temperature and calcium–estrogen relationships in the hen. *Poultry Science* 75, 1555–1562.

Maria, G., Cepero, R. and Hernandis, A. (2001) Ethical cages offering an improved environment for laying hens. In: *Jornadas sobre Producción Animal, Zaragoza, Spain*, Extra 22, pp. 505–507.

Marks, H.I., Tindel, L.D. and Lowe, R.H. (1970) Performance of egg production stocks under three cage densities. *Poultry Science* 49, 1094–1099.

Mashaly, M.M., Webb, M.L., Youtz, S.L., Roush, W.B. and Graves, H.B. (1984) Changes in serum corticosterone concentration of laying hens as a response to increased population density. *Poultry Science* 63, 2271–2274.

Martin, G.A. and Carter, T.A. (1980) You'll be better off with one less layer per cage. *Poultry Digest* 39, 340–342.

Martin, G.A., Carter, T.A., West, J.R. and Ward, J.B. (1980) Cage shape and space effects on layers in closed housing. *Poultry Science* 59, 1567.

Maxwell, M.H. (1993) Avian blood leucocyte responses to stress. *World's Poultry Science Journal* 49, 34–43.

McAdie, T.M. and Keeling, L.J. (2002) The social transmission of feather pecking in laying hens: effects of environment and age. *Applied Animal Behaviour Science* 75, 147–159.

Meyer, W.A. and Sunde, M. (1974) Bone breakage as affected by type of housing or an exercise machine for layers. *Poultry Science* 53, 878–881.

Miller, P.C. and Sunde, M.L. (1975) The effects of precise constant and cyclic environments on shell quality and after layer performance factors with leghorn pullets. *Poultry Science* 54, 36–46.

Moinard, C., Movisse, J.P. and Faure, J.M. (1998) Effect of cage area, cage height and perches on feather condition, bone breakage and mortality of laying hens. *British Poultry Science* 39, 198–202.

Mou, L.J. and Katle, J. (1990) Effects of different environments and selection for persistency in laying hens. 2. Egg production performance in laying hens in two different environments (cages vs. floor). *Norwegian Journal of Agriculture* 4, 205–216.

Muir, F.V., Gerry, R.W. and Hawes, R.D. (1980) *Effect of Cage Dimension and Feeding Requirement on the Performance of Chickens Laying Brown Eggs: Research in the Life Sciences* 27. University of Maine at Orono, USA.

Muir, W.M. (1996) Group selection for adaptation to multiple-hen cage: selection program and direct responses. *Poultry Science* 71, 631–633.

Muiruri, H.K. and Harrison, P.C. (1991) Effect of peripheral foot cooling on metabolic rate and thermoregulation of fed and fasted chicken hens in a hot environment. *Poultry Science* 70, 74–79.

Najibid, H. and Al-Yousef, Y. (2001) The effect of incorporating palm oil in the diets of layers fed different energy/protein combination levels and raised in a hot semi-arid condition. *Annals of Agricultural Science Cairo* 46, 423–434.

Newman, S. and Leeson, S. (1998) Effect of housing birds in cages or an aviary system on bone characteristics. *Poultry Science* 77, 1492–1496.

Njoku, P.C. and Nwazota, R. (1989) Effect of dietary inclusion of ascorbic acid and palm oil on the performance of laying hens in a hot tropical environment. *British Poultry Science* 30, 831–840.

Oruwari, B.M., Mbere, O.O. and Sese, B.T. (1995) Effect of supplemental ascorbic acid on performance of laying hens in a tropical environment. *Bulletin of Animal Health and Production in Africa* 43, 203–207.

Otten, L., Morrison, W.D., Braithwaite, L.A. and Smith, J.H. (1989) *Development of Cooled Roosts for Heat-Stressed Poultry: American Society of Agricultural Engineers* 89–408. ASAE, St Joseph, Michigan, pp. 1–13.

Ouart, M.D. and Adams, A.W. (1982) Effects of cage design and bird density on layers. 1. Productivity, feathering and nervousness. *Poultry Science* 61, 1606–1613.

Pearl, R. and Surface, F.M. (1904) *A Biometrical Study of Egg Production in Domestic Fowl. 1. Variation in Annual Egg Production. United States Department of Agriculture, Bureau of Animal Industry Bulletin* 118. USDA, Washington, DC.

Perek, M. and Eckstein, B. (1959) The adrenal ascorbic acid content of molting hens and the effect of ACTH on the adrenal ascorbic content of laying hens. *Poultry Science* 38, 96–105.

Pierre, P.E. (1989) Effects of feeding thriouracil on the performance of laying hens under heat stress. *Bulletin of Animal Health Production in Africa* 37, 379–383.

Puthpongsiriporn, U., Scheideler, S.E., Sell, J.L. and Beck, M.M. (2001) Effects of vitamin E and C supplementation on performance, *in vitro* lymphocyte proliferation, and antioxidant status of laying hens during heat stress. *Poultry Science* 80, 1190–1200.

Puvadolpirod, S. and Thaxton, J.P. (2000a) Model of physiological stress in chickens. 1. Response parameters. *Poultry Science* 79, 363–369.

Puvadolpirod, S. and Thaxton, J.P. (2000b) Model of physiological stress in chickens. 2. Dosimetry of adrenocorticotopin. *Poultry Science* 79, 370–376.

Puvadolpirod, S. and Thaxton, J.P. (2000c) Model of physiological stress in chickens. 3. Temporal patterns of response. *Poultry Science* 79, 377–382.

Puvadolpirod, S. and Thaxton, J.P. (2000d) Model of physiological stress in chickens. 4. Digestion and metabolism. *Poultry Science* 79, 383–390.

Rauch, H.W. and Sherwin, C.M. (1994) Results and experiences with laying hens in get-away cages. In: *Proceedings of a Symposium on Modified Cages for Laying Hens.* Nobel House, London, pp. 63–74.

Robinson, D. (1979) Effects of cage shape, colony size, floor area and cannibalism preventatives on laying performance. *British Poultry Science* 20, 345–356.

Roush, W.B., Mashaly, M.M. and Graves, H.B. (1984) Effect of increased bird population in a fixed cage area on production and economic responses of single comb White Leghorn laying hens. *Poultry Science* 63, 45–49.

Sahin, R. and Kucuk, O. (2001) A simple way to reduce heat stress in laying hens as judged by egg laying, body weight gain and biochemical parameters. *Acta Veterinaria Hungarica* 49, 421–430.

Sahota, A.W., Ullah, M.F. and Gillani, A.H. (1993) Effect of heat stress on egg quality characteristics and serum calcium levels of White Leghorn and Lyallpur Silver Black breeds of chickens. *Pakistan Veterinary Journal* 13, 194–197.

Samara, M.H., Robbins, K. and Smith, M.O. (1996) Interaction of feeding time and temperature and their relationship to performance of the broiler breeder hen. *Poultry Science* 75, 34–41.

Schaar, U. (1996) Prevalence of *Salmonella enteritidis* and *Salmonella typhimurium* in laying hens kept in battery cages or floor pens, detected by bacteriological and serological methods. PhD thesis, Fachbereich Veterinarmedizin, Justus-Liebig-Universität Giessen, Giessen, Germany.

Scheideler, S.E., Puthpongsiriporn, U. and Sell, J.L. (2001) Vitamin E and heat stress in layers. *Zootechnology International* 3, 40–45.

Selmi, H. and Horst, P. (1983) Laying persistency as criterion of productivity adaptability of hens under warm environments. In: *Proceedings of the V World Conference on Animal Production. v.2., Free Communication Papers.* Japanese Society of Technology and Science, Tokyo, Japan, pp. 103–104.

Selmi, E. and Horst, P. (1984) Significance of laying persistence for total performance of layers under the influence of environmental temperature and body weight. *Archiv für Geflugelkunde* 48, 8–14.

Sherwin, C.M., Alvey, D.M. and Williamson, J.D. (1993) Effects of cage front design on the feeding behaviour of laying hens. *Applied Animal Behaviour Science* 78, 291–299.

Siegel, H.S. (1959) Egg production characteristics and adrenal function in White Leghorns confined at different floor space levels. *Poultry Science* 38, 893–898.

Siegel, H.S. (1971) Adrenals, stress and environment. *World's Poultry Science Journal* 27, 237–349.

Siegel, H.S. (1980) Physiological stress in birds. *BioScience* 30, 529–534.

Siegel, H.S. (1985) Immunological responses as indicators of stress. *World's Poultry Science Journal* 41, 36–44.

Siegel, H.S. (1995) Stress, strains and resistance. *British Poultry Science* 36, 3–22.

Suto, Z., Perenyi, M., Van, L.U. and Pinczes, L. (1994) Effect of housing system on performance of laying hens. *Szaktanaesok* l–4, 22–32.

Sykes, A.H. and Fataftah, A.R.A. (1986) Effect of a change in environmental temperature on heat tolerance in laying fowl. *British Poultry Science* 27, 307–316.

Tanaka, T., Hosoya, H., Watanabe, T., Tanida, H. and Yoshimoto, T. (1993) Effects of type of cage front on behaviour and performance of laying hens. *Japanese Poultry Science* 30, 24–30.

Tauson, R. and Abrahamsson, P. (1996) Modified cages: alternative housing for laying hens. *Fakta-Husdjur* 6, 32–38.

Taylor, A.A. and Hurnik, J.F. (1994) The effect of long-term housing in an aviary and battery cages on the physical condition of laying hens: body weight, feather condition, claw length, foot lesions, and tibia strength. *Poultry Science* 73, 263–273.

Tengvall, H. (1996) The effect of the housing system on the health and behavior of laying hens: a review. *Suomen Elainloakarilehi* 102, 349–354.

Thaxton, J.P. and Puvadolpinod, S. (2000) Model of physiological stress in chickens. 5. Quantitative evaluation. *Poultry Science* 79, 391–395.

Uneo, T. and Komiyama, T. (1987) Genetic variation in tolerance to extreme thermal environments in White Leghorn chickens. *Japanese Poultry Science* 24, 1–7.

USDA (United States Department of Agriculture) (2000) *Federal Legislation No. 132*, July (2000), 69, pp. 2304–2305.

van der Weghe, S. and van der Weghe, H. (2000) The aviary hens system for laying hens: a meaningful alternative for keeping. *Landtechnik* 55, 362–363.

Vanskike, K.P. and Adams, A.W. (1993) Effects of declawing and cage shape on productivity, feathering, and fearfulness of egg type chickens. *Poultry Science* 62, 708–711.

Wall, H. and Tauson, R. (2002) Egg quality in furnished cages for laying hens: effects of crack reduction measures and hybrids. *Poultry Science* 81, 340–348.

Warren, D.C. and Schnepel, R.L. (1940) The effect of air temperature on egg shell thickness in the fowl. *Poultry Science* 19, 67–72.

Wilson, W.D., Itoh, S. and Siopes, T.D. (1972) Production traits of leghorn pullets in controlled temperatures. *Poultry Science* 51, 1014–1023.

Wolford, J.H. and Ringer, R.K. (1962) Adrenal weight, adrenal ascorbic acid, adrenal cholesterol and differential leukocyte counts as physiological indicators of 'stressor' agents in laying hens. *Poultry Science* 41, 1521–1529.

Zulovich, J.M. and DeShazer, J.A. (1987) *Temperature Humidity Index for Laying Hens. American Society of Agricultural Engineers* 87. ASAE, St Joseph, Michigan.

PART III
Welfare issues

CHAPTER 11
Genetic influences on resource use, fear and sociality

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ABSTRACT

Numerous behavioural traits vary substantially between and within breeds of poultry. Many of these traits respond rapidly to genetic selection and show moderate to high heritability, illustrating the potential for selective breeding to promote welfare-friendly traits and to minimize deleterious ones. Selection criteria must fulfil certain requirements to achieve practical relevance: ideally the selected character must be relevant to conditions in all housing systems and the selection process must be affordable. Furthermore, breeding programmes intended to improve adaptability and welfare should aim to modify the underlying motivational states which trigger the unwanted physiological traits rather than merely minimizing their symptoms. Strain differences in the use of various resources (e.g. nestboxes, dust baths, perches) by laying hens indicate a genetic basis for the corresponding behaviours. However, selection for the use of specific resources may have limited value because of the rapid evolution of housing systems. On the other hand, low levels of fearfulness and stress susceptibility are clearly desirable for domestic animals. Genetic selection of Japanese quail for long or short tonic immobility fear reactions and for high or low adrenocortical responses to restraint exerted non-specific, beneficial effects on fearfulness and stress susceptibility and revealed parallel evolution of the two characters. Furthermore, following selective breeding for high rather than low social reinstatement behaviour, which increased the underlying sociality of the birds, the quail showed more affiliative and sexual behaviour. However, higher levels of non-aggressive pecking and feather pecking in these birds indicate the need for caution. More encouragingly, domestic chicks that ran a T-maze quickly to regain social contact showed greater sociality, faster growth, accelerated puberty and lower adrenocortical responses to an acute stressor than their slower counterparts. These findings suggest that selection for reduced fearfulness and stress susceptibility, and maybe also appropriate sociality, is likely to improve adaptability and welfare.

INTRODUCTION

In the ongoing debate about the welfare of farm animals, the most frequently identified remedial measures involve developing practical improvements to housing

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systems or increasing the animal's ability to adapt to its environment (Faure, 1980). Sadly, they are often wrongly regarded as alternative rather than complementary strategies. Thus, whereas alternative 'welfare-friendly' systems are considered desirable, genetic selection for increased adaptability often raises ethical objections, largely centred on unfounded claims that it would change the animals' 'nature' or transform them into brainless pieces of meat. However, behavioural changes accompanying selection are quantitative rather than qualitative, i.e. it is thresholds of response rather than the responses themselves that are changed (Price, 1999). Ideally, we should integrate environmental and genetic approaches to maximize welfare, productivity and product quality (Faure, 1980; Jones and Hocking, 1999). In this chapter, we focus on genetic influences on various behaviour patterns as a prerequisite to selective breeding.

Most domesticated species share common characteristics, e.g. living in large hierarchical groups, promiscuous mating, precocial young, low fear, and acceptance of diverse foods. The efficiency of selecting for an exaggeration of favourable characters during domestication is clearly demonstrated by comparisons with wild ancestors or feral counterparts. The most commonly reported behavioural effects of domestication in poultry include reductions in aggression and fear (Jones, 1996; Faure *et al*., 2003). Practical relevance demands that selection criteria must fulfil at least two requirements: (i) the selected characteristic must not be specific to a particular environment otherwise its relevance may be overtaken by the rapid evolution of housing systems; and (ii) the selection process must be affordable (this depends on the complexity and cost of the behavioural tests and the heritability of the character (see Faure, 1981)).

Numerous behavioural and physiological traits respond to genetic selection in poultry, and many show moderate to high heritability (Faure *et al*., 2003). In a broad-brush approach we consider their welfare significance. Behavioural traits such as fearfulness (the predisposition to be easily frightened) and sociality (the motivation to be near conspecifics) can exert profound effects on welfare (Jones, 1996; Faure and Mills, 1998; Jones and Hocking, 1999). We also pay close attention to physiological measures of stress susceptibility as well as to the birds' motivation to use particular resources. The latter aspect clearly illustrates the complementarity of genetic and environmental approaches.

RESOURCE USE

Relatively little research has focused on the genetics of resource usage by laying hens, and their welfare implications. Furthermore, the few studies have been spread across various resources – nests, space, dust baths, perches, enrichment stimuli. We discuss genetic determinism and the potential welfare consequences of selection for expression of behaviour patterns associated with these resources.

Nests

The nest provides a place for the hen to lay its egg and perhaps incubate it. Incubation behaviour is almost absent in modern strains. It has not been eliminated but its threshold has increased to such an extent that its expression is rare (Faure

et al., 2003). In the wild, a hen usually lays her egg in a sheltered place on the ground. Apart from traditional battery cages, all systems incorporate nestboxes that offer some shelter and seclusion during pre-laying and oviposition; these are usually raised off the ground to facilitate egg collection and nest cleaning. However, eggs are sometimes laid on the floor, perhaps because a human's preconception of a suitable nest site may differ from a hen's and because the evaluation of nest quality may vary across birds. Failure to use nestboxes may have no direct welfare implications but it is an economic problem because egg collection becomes labour-intensive and the eggs are often broken or dirty, thereby reducing value and hatchability (Appleby *et al*., 1992). Early experience can influence the hens' use of nestboxes but there may also be a genetic component. Until the 1960s, breeding hens were provided with trap nests and floor layers were discarded. However, subsequent housing in battery cages and the associated relaxation of selection pressure against floor laying may explain the observed increase in floor eggs. Strain differences also imply that the use of nestboxes is under genetic control. Behaviours expressed in the absence of a nest, such as vacuum nest building and stereotyped pacing, may cause concern. Selective breeding could minimize their occurrence but, since the relationships between these behaviours and welfare is not sufficiently clear, it is difficult to identify the most beneficial selection programme (Mills *et al*., 1985).

Activity, Time and Space

Strain differences in activity are common (Savory and Mann, 1997), with heavy birds being the least active. Although genetic correlations between body weight and activity revealed the reverse relationship and heritabilities of activity were relatively low (0.10–0.20: Jezierski and Bessei, 1978), the genetic control of activity may merit further research because the increases in activity (paces, wing flaps) from cages to percheries to Elson terraces or deep litter were associated with increased bone strength (Knowles and Broom, 1990). However, differences in activity between housing systems might exceed those achievable through selection. Time budgets also vary substantially between strains, e.g. wild or feral fowl spend longer foraging than modern laying strains (Vilariño *et al*., 1996). In free-range layers, a Leghorn cross also ventured on to the range oftener and moved greater distances than a Rhode Island cross (von Borell *et al*., 2002).

Food

Genetic differences in food intake and nutrient selection are evident, but effort has focused either on comparisons of broiler strains or of broilers versus layers. For example, heavy lines of broilers ate more and oftener than either lighter ones or layers, and broilers balanced their intake of energy- and protein-rich diets, whereas layers ate a higher proportion of proteins (Yo, 1996). However, such strain differences have little direct relevance to welfare if the birds are provided with sufficient amounts of a balanced diet.

Dust Baths

Dust bathing (DB) is a genetically fixed, invariable comfort behaviour in which hens work dust or other loose material into the feathers, where it helps to remove oily secretions and control parasites (Appleby *et al*., 1992). Since standard battery cages do not provide the necessary substrate it was assumed that hens might suffer, although the 'out of sight, out of mind' argument could also apply. In this context, vacuum dust bathing could be variously interpreted in terms of high motivation, deprivation-induced frustration, or simply a low behavioural threshold (Appleby *et al*., 1992).

Divergent selection of two lines of Japanese quail showing high and low DB (heritability of 0.28) indicated that the behaviour is under tight genetic control (Gerken, 1991). Realized heritabilities of 0.18 and 0.38 in the high and low lines indicated an asymmetrical response to selection. However, these quail had never experienced dust before so the line differences may have reflected contrasting levels of novelty-induced fear (Jones and Hocking, 1999). Regardless of the underpinning mechanism, plumage condition was better in high DB quail but the direction and value of any selection programme is unclear. For example, decreased motivation for DB in the low line might reduce their need for a specialized substrate but a lower threshold might mean that vacuum DB would satisfy those of the high line. Moreover, the welfare benefits of selection are debatable, given the apparently equivocal nature of dust-bathing motivation (Appleby *et al*., 1992).

Perches

Perches will be incorporated into all new European housing systems for laying hens but little attention has been paid to the role of the background genome despite early reports of sex differences and of variation between and within strains for perching behaviour (Faure and Jones, 1982a,b). Reports that both pen- and cage-housed hens (Hughes and Elson, 1977; Lambe and Scott, 1998) also showed considerable individual variation in perching should sound further cautionary notes concerning the design of alternative systems, particularly in view of marked differences in the ability of laying hens to negotiate downward jumps from perches and the attendant increased risk of injury (Moinard *et al*., 2004). Although perch provision will become mandatory in Europe (EU), this only represents 10% of the world's laying hen population so it is unlikely that commercial selection will be undertaken on this character.

Light

Light is a critical environmental variable; its many facets and the search for optimal lighting systems are fully described elsewhere in this book (see chapters by Perry and Prescott *et al*.). Therefore, we restrict comment to the fact that eight generations of selection for choices between blue and red light in quail also modified their responses to other colour combinations (Kovach, 1978). However, the potential of this type of genetic selection for improving welfare seems limited.

Environmental Stimulation

Chickens' development and welfare are profoundly affected by environmental dynamics as well as the genome (Jones, 2002) but the importance of genotype × environment interactions is sometimes underestimated (Jones and Hocking, 1999). Most relevant studies have used the Japanese quail. For example, the fear-reducing effects of early environmental enrichment and regular handling were more pronounced in quail bred for short (STI) rather than long (LTI) tonic immobility fear reactions (Jones *et al.*, 1991; Mills and Faure, 1991), suggesting that sensitivity to early stimulation was related to differences in fearfulness. Unlike LTI quail, STI birds did not form a conditioned aversion to coloured mildly toxic food (Faure *et al.*, 2003). Quail selected for high (HSR) or low (LSR) social reinstatement motivation also differed in their use of conspecific cues. Birds of both lines showed similar responses to a novel food when tested alone but HSR birds fed sooner and ate more when they could see other quail eating this food, whereas LSR quail were unaffected (Faure and Mills, 1998).

FEAR AND SUSCEPTIBILITY TO STRESS

Fear is a major emotion governing an animal's life. Ideally it is adaptive but in reality the restrictions imposed by many farming systems can interfere with the birds' ability to respond adaptively. For example, caged hens cannot run away from danger. Inappropriate fear responses, such as panic, can waste energy and cause injury, pain or death (Jones, 1996). Fearful chickens also show poorer productivity and product quality than less fearful ones (Mills and Faure, 1990; Jones, 1996; Jones and Hocking, 1999). Fear inhibits all other behavioural states (Jones, 1996) so its elicitation compromises the bird's ability to interact successfully with its companions or the stockperson, to utilize new resources and to adapt to changes in the environment. Similarly, despite their ideally adaptive role in maintaining bodily homeostasis, the corticosteroids may counter-regulate and exert harmful effects such as immunosuppression and decreased reproductive performance (Jones, 1996). Chronically elevated levels of corticosterone also increase underlying fearfulness, thereby exacerbating the adrenocortical stress response and establishing a vicious circle (Jones *et al.*, 1988).

Although domestication has resulted in increased docility, individual and strain differences in fear and adrenocortical activation illustrate the scope for further genetic improvement (Jones and Hocking, 1999; Faure *et al.*, 2003). Selection for high ambulation in a novel arena was associated with reduced fearfulness in domestic chicks (Faure, 1981). However, most studies used the Japanese quail because it is a good low-cost model for the domestic fowl as well as an important agricultural species in many countries (Faure and Mills, 1998). Thus, quail were selected for long (LTI) or short (STI) durations of tonic immobility (TI) reactions to manual restraint (Mills and Faure, 1991) and for exaggerated (high stress, HS) or reduced (low stress, LS) plasma corticosterone (C) responses to mechanical immobilization (Satterlee and Johnson, 1988). Significant differences between the TI lines were apparent in the first generation and the absence of overlap between the standard deviations from G8 onwards suggests that they had become distinct genetic lines. Despite occasional relaxation of selection

pressure, divergence was also maintained between the HS and LS quail (Jones and Satterlee, 1996).

These selection programmes would have little relevance if the selected responses were specific to the test situations. Encouragingly, though, selection modified the quail's responses to a wide range of intuitively frightening and otherwise stressful events. Thus, compared with LTI and HS quail, the STI and LS birds showed attenuated TI reactions, less behavioural inhibition, reduced avoidance of novel objects and human beings, and accelerated emergence into exposed environments (Jones *et al*., 1991, 2000; Jones and Satterlee, 1996). Thus, selection of the STI and LS lines was accompanied by reductions in fearfulness. Elevations in plasma C levels were lower in LS than in HS quail in response to a range of stressful events, including manual restraint, cold, crating, social tension, and fasting (Satterlee and Johnson, 1988; Jones *et al*., 2000). Fluctuating asymmetry, an indicator of chronic stress, was also lower in LS quail, suggesting that selection for reduced fear and distress may increase the birds' ability to produce stable phenotypes (Satterlee *et al*., 2000). Unlike LS quail, which showed no detectable effects of repeated restraint, the HS birds showed experience-dependent sensitization (Jones *et al*., 2000). This finding has far-reaching implications because chronic elevation of plasma C can increase fearfulness and damage disease resistance (Gross and Siegel, 1993; Jones *et al*., 1988). Thus, if a proportion of the laying hen population showed similar sensitization of the C response, this could increase their susceptibility to stress and thereby compromise their health, productivity and product quality. In this context, stress-induced reductions in meat quality were less pronounced in STI than LTI quail (Faure and Mills, 1998), growth rate and bone strength were less severely reduced in stressed LS than HS quail (Satterlee and Roberts, 1990), and puberty was accelerated in LS birds (Marin *et al*., 2002).

Traits can be affected by different genes during ontogeny and this may compromise their stability (Nol *et al*., 1996). However, because divergence was still apparent in 10-week-old STI and LTI quail and at 30 weeks in LS and HS birds, the selected traits are probably stable (Faure *et al*., 2003).

These findings provide a platform for future studies in more commercially important species, and these could lead to marker-assisted selection to maintain or remove specific gene alleles. The overall objective is to increase the birds' ability to adapt to challenge and thereby improve welfare and performance. Since adaptability is shaped by the environment as well as the genome, environmental enrichment and selective breeding approaches should be integrated (Jones and Hocking, 1999).

SOCIALITY

Early selection programmes focused heavily on aggression and social dominance (see Craig *et al*., 1965) but positive social behaviours are receiving growing interest, with selection oriented to social attraction to an imprinting stimulus in chickens (Graves and Siegel, 1969) and conspecifics in Japanese quail (Mills and Faure, 1991). In the latter case, quail were selected for distance run on a treadmill to maintain close contact with conspecifics, i.e. reinstatement. Line divergence between quail showing low (LSR) or high (HSR) social reinstatement was soon evident. The HSR quail also showed more jumping and peeping and greater

elevations of plasma C levels and heterophil/lymphocyte ratios upon isolation than LSR birds (Mills *et al*., 1993). They also spent longer in visual or physical contact than LSR birds up to 3–4 weeks of age, although these effects were apparent at 5–6 weeks only when physical contact was prevented (Faure *et al*., 2003). HSR males and females also copulated sooner, more often and with greater efficiency than the LSR group (Burns *et al*., 1998). Furthermore, HSR birds were easier to capture, perhaps because they were less frightened of humans (Faure *et al*., 2003). One interpretation of line differences in social reinstatement, sexual behaviour and fear of humans is that selection has altered the birds' general ability to imprint. At first it was thought that HSR birds would adapt more easily to normal rearing conditions (large, high-density groups) but observations that adult HSR quail showed greater reinstatement only if social contact was prevented and that they show more non-aggressive pecking and feather pecking (Faure *et al*., 2003) indicate the need for caution.

Although no selection programme was conducted, a simple T-maze test provided a quick, robust measure of social motivation in broiler chicks (see Jones *et al*., 1999; Marin *et al*., 2003). Chicks that negotiated the T-maze quickly in order to regain social contact showed lower plasma C responses to an acute stressor and put on more weight than their slower counterparts, both in the laboratory and at a commercial farm (see Marin and Jones, 1999; Marin *et al*., 2003). If T-maze behaviour was open to selection it might offer a quick and cheap alternative to the treadmill test and thereby offer a useful technique to select for appropriate levels of social motivation.

DISCUSSION

A common question is whether genetic selection for increased adaptability in poultry will affect productivity. There are three possible scenarios. First, selection for adaptability might damage production. However, as far as we know, this has never been reported. Neither is it likely because increased adaptability implies a greater likelihood of coping successfully with extraneous challenges that might otherwise impair performance. Second, selection for adaptability may have no effect on production. This could be the case if selection for production was unconsciously associated with indirect selection for adaptability. For example, the indirect selection for reduced fear that accompanied domestication may have combated the reduction in reproductive performance that highly fearful wild animals would have otherwise shown in captivity. Third, selection for adaptability may unconsciously improve productivity. Examples include the alleviation of stress-induced reductions in product quality and bone strength in STI and LS quail (see above). Furthermore, appropriate levels of sociality might improve all aspects of social interaction, reduce social stress, and thereby increase welfare and performance (Jones and Hocking, 1999; Jones and Mills, 1999). It is pertinent to note that birds are housed individually in many breeding programmes rather than in social situations that would allow the expression of (and selection for) aspects of social behaviour.

Rapid responses were observed in all the selection experiments described here and the associated heritabilities were moderate to high, illustrating the potential for further genetic improvement. Some rapid tests have already either been used or identified as selection criteria for breeding programmes (see Jones and Hocking,

1999; Faure *et al*., 2003). Their execution takes longer than the measurement of body weight but much less time than the assessment of laying rates. Moreover, appropriate automation could easily reduce the time required to carry out these tests and thereby decrease the associated costs.

Breeding programmes intended to improve adaptation and welfare should focus on characters that are likely to be influential in all current and future housing systems. Thus, in order for artificial selection to effectively improve welfare it should be directed at changing underlying motivational states rather than simply suppressing undesirable symptoms of those motivations. The significant reduction in underlying fearfulness that accompanied selection of quail for shorter TI fear reactions or for decreased adrenocortical responses to mechanical restraint (Faure and Mills, 1998; Jones and Hocking, 1999; Jones *et al*., 1991, 2000) suggests that such breeding programmes could meet these criteria, as may the modification of sociality. Conversely, selection for resource use has limited interest, particularly since rearing environments are changing quickly because of technical or legal constraints, whereas selection is a long-term process.

To conclude, genetic selection is becoming widely accepted as a quick, reliable method of eliminating harmful traits and promoting desirable ones in farm animals (see Faure and Mills, 1998; Jones and Hocking, 1999). Selection should aim to improve adaptability to a wide range of environments rather than to a specific one. In some cases, selection for increased adaptability could be applied immediately, whereas others require further research on the associated effects of selection and the relative benefits of environmental alternatives. In view of the beneficial effects of practicable environmental enrichment, an approach that integrates genetic and environmental strategies is the most likely to satisfy the birds', the farmers' and the public's requirements.

REFERENCES

Appleby, M.C., Hughes, B.O. and Elson, H.A. (1992) *Poultry Production Systems: Behaviour, Management and Welfare*. CAB International, Wallingford, UK.

Burns, M., Domjan, M. and Mills, A.D. (1998) Effects of genetic selection for fearfulness or social reinstatement behavior on adult social and sexual behavior in domestic quail (*Coturnix japonica*). *Psychobiology* 26, 249–257.

Craig, J.V., Ortman, L.L. and Guhl, A.M. (1965) Genetic selection for social dominance ability in chickens. *Animal Behaviour* 13, 114–131.

Faure, J.-M. (1980) To adapt the environment to the bird or the bird to the environment. In: Moss, R. (ed.) *The Laying Hen and Its Environment*. Martinus Nijhoff, The Hague, The Netherlands, pp. 19–42.

Faure, J.-M. (1981) Bidirectional selection for open-field activity in young chicks. *Behavior Genetics* 11, 135–144.

Faure, J.-M. and Jones, R.B. (1982a) Effects of sex, strain and type of perch on perching behaviour in the domestic fowl. *Applied Animal Ethology* 8, 281–293.

Faure, J.-M. and Jones, R.B. (1982b) Effects of age, access and time of day on perching behaviour in the domestic fowl. *Applied Animal Ethology* 8, 357–364.

Faure, J.-M. and Mills, A.D. (1998) Improving the adaptability of animals by selection. In: Grandin, T. (ed.) *Genetics and the Behaviour of Domestic Animals*. Academic Press, San Diego, USA, pp. 235–264.

Faure, J.-M., Bessei, W. and Jones, R.B. (2003) Direct selection for improvement of animal well-being. In: Muir, W.M. and Aggrey, S.E. (eds) *Poultry Genetics, Breeding and Technology*. CAB International, Wallingford, UK, pp. 221–245.

Gerken, M. (1991) *Antagonistische Beziehungen zwischen Verhaltens und Leistungsmerkmalen beim Geflügel*. Habilitationsschrift, Bonn University, Germany.

Graves, H.B. and Siegel, P.B. (1969) Bidirectional selection for responses of *Gallus domesticus* chicks to an imprinting situation. *Animal Behaviour* 17, 683–691.

Gross, W.B. and Siegel, P.B. (1993) General principles of stress and welfare. In: Grandin, T. (ed.) *Livestock Handling and Transport*. CAB International, Wallingford, UK, pp. 21–34.

Hughes, B.O. and Elson, H.A. (1977) The use of perches by broilers in floor pens. *British Poultry Science* 18, 715–722.

Jezierski, T. and Bessei, W. (1978) Der Einfluss von Genotyp und Umwelt auf die lokomotorische Aktivität von Legehennen in Käfigen. *Archiv für Geflügelkunde* 42, 159–166.

Jones, R.B. (1996) Fear and adaptability in poultry: insights, implications and imperatives. *World's Poultry Science Journal* 52, 131–174.

Jones, R.B. (2002) Role of comparative psychology in the development of effective environmental enrichment strategies to improve poultry welfare. *International Journal of Comparative Psychology* 15, 1–29.

Jones, R.B. and Hocking, P.M. (1999) Genetic selection for poultry behaviour: big bad wolf or friend in need? *Animal Welfare* 8, 343–359.

Jones, R.B. and Mills, A.D. (1999) Divergent selection for social reinstatement behaviour in Japanese quail: effects on sociality and social discrimination. *Poultry and Avian Biological Review* 10, 213–223.

Jones, R.B. and Satterlee, D.G. (1996) Threat-induced behavioural inhibition in Japanese quail genetically selected for contrasting adrenocortical response to mechanical restraint. *British Poultry Science* 37, 465–470.

Jones, R.B., Beuving, G. and Blokhuis, H.J. (1988) Tonic immobility and heterophil/lymphocyte responses of the domestic fowl to corticosterone infusion. *Physiology and Behaviour* 42, 249–253.

Jones, R.B., Mills, A.D. and Faure, J.-M. (1991) Genetic and experiential manipulation of fear-related behaviour in Japanese quail chicks (*Coturnix coturnix japonica*). *Journal of Comparative Psychology* 105, 15–24.

Jones, R.B., Marin, R.H., Garcia, D.A. and Arce, A. (1999) T-maze behaviour in domestic chicks: a search for underlying variables. *Animal Behaviour* 58, 211–217.

Jones, R.B., Satterlee, D.G., Waddington, D. and Cadd, G.G. (2000) Effects of repeated restraint in Japanese quail genetically selected for contrasting adrenocortical responses. *Physiology and Behaviour* 69, 317–324.

Knowles, T.G. and Broom, D.M. (1990) Limb bone strength and movement in laying hens from different housing systems. *Veterinary Record* 126, 354–356.

Kovach, J.K. (1978) Colour preference in quail chicks: generalisation of the effects of genetic selection. *Behaviour* 65, 263–269.

Lambe, N.R. and Scott, G.B. (1998) Perching behaviour and preferences for different perch designs among laying hens. *Animal Welfare* 7, 203–216.

Marin, R.H. and Jones, R.B. (1999) Latency to traverse a T-maze at 2 days of age and later adrenocortical responses to an acute stressor in domestic chicks. *Physiology and Behaviour* 66, 809–813.

Marin, R.H., Satterlee, D.G., Cadd, G.G. and Jones, R.B. (2002) T-maze behaviour

and early egg production in Japanese quail selected for contrasting adrenocortical responsiveness. *Poultry Science* 81, 981–986.

Marin, R.H., Satterlee, D.G., Castille, S.A. and Jones, R.B. (2003) Early T-maze behaviour and broiler growth. *Poultry Science* 82, 742–748.

Mills, A.D. and Faure, J.-M. (1990) Panic and hysteria in domestic fowl: a review. In: Zayan, R. and Dantzer, R. (eds) *Social Stress in Domestic Animals*. Kluwer Academic, Dordrecht, The Netherlands, pp. 248–272.

Mills, A.D. and Faure, J.-M. (1991) Divergent selection for duration of tonic immobility and social reinstatement behaviour in Japanese quail (*Coturnix coturnix japonica*) chicks. *Journal of Comparative Psychology* 105, 25–38.

Mills, A.D., Wood-Gush, D.G.M. and Hughes, B.O. (1985) Genetic analysis of strain differences in pre-laying behaviour in battery cages. *British Poultry Science* 26, 187–197.

Mills, A.D., Jones, R.B., Faure, J.-M. and Williams, J.B. (1993) Responses to isolation in Japanese quail genetically selected for high or low sociality. *Physiology and Behaviour* 53, 183–189.

Moinard, C., Statham, P., Haskell, M.J., McCorquodale, C., Jones, R.B. and Green, P.R. (2004) Accuracy of laying hens in jumping upwards and downwards between perches in different light environments. *Applied Animal Behaviour Science* 85, 77–92.

Nol, E., Cheng, K. and Nichols, C. (1996) Heritability and phenotypic correlations of behaviour and dominance rank of Japanese quail. *Animal Behaviour* 33, 367–380.

Price, E.O. (1999) Behavioural development in animals undergoing domestication. *Applied Animal Behaviour Science* 65, 245–271.

Satterlee, D.G. and Johnson, W.A. (1988) Selection of Japanese quail for contrasting blood corticosterone response to immobilization. *Poultry Science* 67, 25–32.

Satterlee, D.G. and Roberts, E.D. (1990) The influence of stress treatment on femur cortical bone porosity and medullary bone status in Japanese quail selected for high and low blood corticosterone response to stress. *Comparative Biochemistry and Physiology* 95A, 401–405.

Satterlee, D.G., Cadd, G.G. and Jones, R.B. (2000) Developmental instability in Japanese quail genetically selected for contrasting adrenocortical responsiveness. *Poultry Science* 79, 1710–1714.

Savory, C.J. and Mann, J.S. (1997) Behavioural development in groups of pen-housed pullets in relation to genetic strain, age and food form. *British Poultry Science* 38, 38–47.

Vilariño, M., Picard, M., Melcion, J.P. and Faure, J.-M. (1996) Behavioural adaptation of laying hens to dilution of diets under mash and pellet form. *British Poultry Science* 37, 895–907.

von Borell, E., Müller, J. and Mahboub, H. (2002) Monitoring the frequency and duration of run visits by laying hens of different genotype. In: *36th Congress of the ISAE*, Egmond am Zee (NL), 125.

Yo, T. (1996) Adaptation comportementale au choix alimentaire du poulet de chair et de la poule pondeuse (*Gallus domesticus*) en milieu tropical. Thesis, University of Rennes, France.

CHAPTER 12
The genetics of feather pecking and cannibalism

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ABSTRACT

Feather pecking and cannibalism are important welfare issues in the battery cage system and even more of a problem in alternative systems of egg production. Interest in the genetics of feather pecking and cannibalism has grown in the last few decades and a genetic solution might be more sustainable, efficacious and cost-effective than environmental modifications. Strain differences in the plumage condition of laying hens and feather pecking behaviour have been reported. More recently within-line genetic components of feather pecking and cannibalism have been quantified. Estimates of the heritability of plumage condition range from moderate (0.22) to high (0.54) and the heritability of observations of pecking behaviour from 0.06 to 0.38. Some selection experiments have produced little or no evidence of a response. However, in one experiment, group selection was very effective in reducing the incidence of beak-inflicted injuries in caged hens and realized family heritability was 0.65 ± 0.13. Divergent selection for high and low feather pecking resulted in significant differences in feather pecking behaviour and plumage condition. There is uncertainty about the correlated responses to selection for low feather pecking and cannibalism, and this justifies more research. Molecular approaches may offer the opportunity for selection to decrease feather pecking and cannibalism without compromising the welfare of birds in the selected flock. However, the evidence so far is not encouraging, and future opportunities to change the propensity for damaging feather pecking and cannibalism in commercial laying hens will probably rely on conventional selection in appropriate environments.

INTRODUCTION

Interest in the genetics of feather pecking and cannibalism has grown in the last few decades in connection with major changes in production systems. Genotypes specialized in a very high egg output have been developed (Flock and Heil, 2002). Concurrently, changes in housing and management, such as keeping birds in very large groups, at high stocking densities, in barren environments, and feeding a mash diet with a very high nutrient concentration, have been introduced. This has

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been associated with behavioural problems such as feather pecking and cannibalism, and remedial measures such as beak trimming have been implemented to overcome them. Beak trimming introduces welfare problems of its own by inflicting pain in the short and long term (Gentle, 1986; Gentle *et al.*, 1990, 1997). Production systems and methods can be changed to reduce problems, but often with severe economic consequences. In the longer term, a genetic solution might be more effective, and this chapter will examine the feasibility of this proposal.

This chapter includes a review of research that investigates the genetic background of feather pecking and cannibalism. It should be noted, however, that there are many ways of defining these traits or, alternatively, there might be several traits covered under the same term of feather pecking and cannibalism. It is therefore necessary to define these terms.

WHAT IS FEATHER PECKING AND WHAT IS CANNIBALISM?

In general, one can differentiate between self-pecking and allo-pecking. If a bird pecks itself, it will normally be preening its feathers, but if the plumage, toes or skin are damaged it is referred to as *self-pecking* or *self-mutilation*. Preening other birds (*allo-preening*) is pecking the plumage of other birds without doing harm, and is often done in a non-aggressive social context (Harrison, 1965). Pecking harmfully at other birds is referred to as *allo-pecking*. *Aggressive pecking* is forceful allo-pecking usually directed at the facial region (Kruijt, 1964). Feathers can be damaged, but it is generally acknowledged that aggressive pecking is not a major cause of feather loss.

The typical 'feather pecking act' has been described and illustrated by Wennrich (1975). The hen performing feather pecking slowly approaches the target hen (recipient) from behind or from the side, focusing on the feathers of the recipient. The recipient will in most cases pay no attention to the performer at first, but will often move away after having received some feather pecks, the response depending on the severity of the pecks. The following types of pecking have been reported: pecking without removal of feathers, causing little damage, such as barb pulling (Hughes, 1973); barb pecking (Savory, 1995); gentle pecking (Keeling, 1995); and stereotypic pecking (Bessei, 1983; Kjaer and Vestergaard, 1999) or pecking causing damage such as feather removal (Hughes, 1973), feather pulling (Savory, 1995) and severe pecking (Keeling, 1995). Feather pulling can result in severe damage of the integument, including bleeding from feather follicles (Hughes and Duncan, 1972). Distinguishing between damaging and non-damaging pecking can in certain cases be very subjective, and objective methods of classification are still needed.

Birds may be wounded by allo-pecking and even pecked to death. This is called cannibalism and is regarded by some authors as the final phase of severe feather pecking (e.g. Bessei, 1983; Blokhuis and Arkes, 1984; Savory and Mann, 1997). Cannibalism can occur without previous feather pecking and may involve damaging pecking at non-feathered areas like the feet. However, this form of pecking is mostly directed at the cloaca and is referred to as cloacal cannibalism, 'vent-pecking' (Hughes and Duncan, 1972; Allen and Perry, 1975), 'bloody cloaca' (Madsen, 1966) and 'pick-outs' (Neal, 1956). Cloacal pecking may be related to prolapse occurring at the beginning of the laying period or simply to

normal exposure of the proximal end of the oviduct or vent at the end of the laying process. Feather pecking is not necessarily a precursor of cannibalism, but high rates of feather pecking do increase the risk of cannibalism (Huber-Eicher, 1997; Wechsler *et al*., 1998; Kjaer and Sørensen, 2002).

STRAIN DIFFERENCES

Strain and cross differences were reported in an early study by Richter (1954). He crossed different strains with partridge-coloured Leghorns, known to feather peck. These crosses gave very different results: one cross showed hardly any feather pecking, whereas the other demonstrated high rates of feather pecking. He also concluded that feather pecking was transmitted to the offspring as 'a hereditary factor'. Since then a large number of authors have reported strain differences in plumage condition of laying hens, e.g. Ambrosen and Petersen (1997), Abrahamsson and Tauson (1995), Bessei (1984a), Conson and Petersen (1986), Damme and Pirchner (1984), Grashorn and Flock (1987), Hughes and Duncan (1972), Ouart and Adams (1982) and Tind and Ambrosen (1988). Strain differences in observed feather pecking behaviour have also been reported (Tind and Ambrosen, 1988; Blokhuis *et al*., 1993).

In a multi-strain comparison of 12 commercial layer and 13 unselected traditional lines, we have shown that there is considerable between-breed genetic variation for feather scores, skin lesions and cannibalism (P.M. Hocking *et al*., unpublished, see Table 12.1). Comparatively little breed variation was observed for time spent on general behaviours and measures of fear and sociality suggesting, in contrast to feather pecking and cannibalism, that these behaviours were relatively unaffected by different selection strategies. Interestingly, feather pecking and cannibalism occurred in traditional and commercial lines and genetic variation in the two categories was similar to the overall estimate (Table 12.1). The important conclusions are that although selection for high productivity may have increased the prevalence of feather pecking and cannibalism, this is not inevitable, and that these behaviours commonly occur in traditional as well as current, highly productive, selected lines. Furthermore, some lines showed feather loss with little cannibalism

Table 12.1. Between-breed intraclass correlations for the proportion of birds culled or dying from cannibalism (mortality), proportion with feather damage, and the proportion with skin lesions in 25 lines of chickens at 30 weeks of age. The intraclass correlations were determined over all 25 lines (t_b) or with category (commercial or traditional) included in the statistical model (t_{bw}). Means for commercial and traditional lines are presented as back-transformed means. (From Hocking *et al*., 2004.)

			Category means		
Trait	t_b	t_{bw}	Commercial	Traditional	Significance
Mortality (probability of death)	0.30*	0.15	0.19	0.06	*
Severe skin score (probability)	0.73*	0.69*	0.26	0.08	NS
Severe feather damage (probability)	0.51*	0.52*	0.14	0.19	NS

* $P < 0.05$; NS = not significant.

and others with high mortality and little or no evidence of feather loss. Mortality in some lines was associated with toe and foot pecking and not with the usual target areas of the tail, vent and the base of the wings.

BIOMETRICAL STUDIES

The nature of the genetic components of feather pecking and cannibalism has not received much attention until recently. The relatively small literature on the quantitative genetics of feather pecking and cannibalism will be reviewed in this section.

Experiments designed for the estimation of genetic parameters have to be extensive. This is due to the properties of variance components, which are the bases of estimating genetic parameters such as heritability. In order to obtain estimates with a reasonable precision, the number of animals has to be large and systematically distributed among sires (males) and dams (females). Individual pedigrees have to be available and observations carried out on individuals or groups of closely related birds.

Plumage condition is relatively easy to score on a large number of birds and various subjective measurements have been used, some including only feather scoring (e.g. Tauson *et al*., 1984), some only skin condition (e.g. Abrahamsson and Tauson, 1995) and some including both in the same score (e.g. Hughes and Duncan, 1972). One should be cautious, however, in the use of plumage condition as an indicator of feather pecking, due to the existence of social facilitation of feather pecking (Savory and Mann, 1997; McAdie and Keeling, 1999). This means that birds have to be kept in family groups, for example consisting of half-sibs, and then the average plumage score of the group will be the data point used for further analyses. If individual scores of these sibs are used there is a risk of introducing a bias due to interdependencies between birds within a group, i.e. the birds are not independent observations but are correlated, and this should be included in the statistical model. Another way of introducing bias is by using full-sib analyses instead of half-sib analyses. This will introduce a possible positive bias due to the method of calculating the variance components (Falconer, 1989). Thirdly, feather pecking can in some cases not be distinguishable from abrasion (Tind, 1985).

Some estimates of heritability of plumage condition are given in Table 12.2. Estimates range from moderate (0.22) to high (0.54). Craig *et al*. (1983) reported that heritability estimates of plumage condition in two White Leghorn strains kept in high-density cages were not significantly different from zero. Grashorn and Flock (1987) found the heritability of plumage condition was very low at the beginning of the laying period and increased with time, suggesting that genetic variability was expressed at greater ages only. This fits well with estimates of heritability obtained directly on feather pecking behaviour at various ages (see below).

Direct observation of pecking behaviour is a more precise method of assessing the tendency to perform feather pecking in individuals and has been used in a few experiments to estimate the heritability of feather pecking. The tendency to receive feather pecking can be measured and heritability estimates for this trait also exist (Table 12.3).

Cuthbertson (1980) reported estimates of heritabilities in a group of

Table 12.2. Estimates of the heritability of plumage condition in strains of layers.

Heritability ± SE	Age (weeks)	Genetic model[a]	Breed[b]	Reference
0.54 ± 0.20	42	Sire	SS	Damme and Pirchner (1984)
0.23 ± 0.13	42	Sire	RIR	Damme and Pirchner (1984)
0.37 ± 0.10	55	Sire+dam	WL	Craig and Muir (1989)
0.34 ± 0.16	59	Sire	SS	Damme and Pirchner (1984)
0.29 ± 0.15	59	Sire	RIR	Damme and Pirchner (1984)
0.37 ± 0.15	60	Sire	WL	Grashorn and Flock (1987)
0.22 ± 0.12	60	Sire	RIR+SS	Grashorn and Flock (1987)
0.22 ± 0.13	67	Sire	RIR	Damme and Pirchner (1984)
0.30 ± 0.15	67	Sire	SS	Damme and Pirchner (1984)

[a]Sire refers to a sire model; sire+dam to a genetic model that includes the dam.
[b]Sussex (SS), Rhode Island Red (RIR), White Leghorn (WL).

approximately 500 chickens of 0.09 ± 0.09 at 3 weeks of age. When she discarded animals that were not observed performing or receiving feather pecking (about 50%) the estimate was higher (0.56 ± 0.26). Bessei (1984a) found a heritability (based on sire and dam components of variance) of 0.20 for performing feather pecking, and 0.25 for being pecked, in 8- to 20-week-old pullets of a strain laying tinted eggs. Estimates of the apparent heritability of performing feather pecking in pullets of a two-line cross (RIR and Sussex) at 18 weeks of age were reported to be only 0.07 ± 0.09, and estimates on receiving feather pecking were also not significantly different from zero (Bessei, 1984b). More recently, Kjaer and Sørensen (1997) reported estimates of performing feather pecking in a White Leghorn strain (310 chickens), using the sire component and animal model. Estimates were of low to moderate size (0.06–0.14 ± 0.07) at 6 and 38 weeks and a little higher (0.35–0.38 ± 0.12) at 69 weeks of age (Table 12.3). Estimates for receiving feather pecking were 0.15 ± 0.07 at 6 weeks of age, but were not significantly different from zero at 38 and 69 weeks of age.

Table 12.3. Estimates of heritability of feather pecking based on direct observations of a single generation of birds.

Heritability ± SE	Age (weeks)	Trait	Reference
0.06 ± 0.07	6	No. of pecks	Kjaer and Sørensen (1997)
0.13 ± 0.07	6	No. of bouts	Kjaer and Sørensen (1997)
0.09 ± 0.09	10	No. of pecks	Cuthbertson (1980)
0.07 ± 0.09	18	No. of pecks	Bessei (1984b)
0.14 ± 0.07	38	No. of pecks	Kjaer and Sørensen (1997)
0.13 ± 0.07	38	No. of bouts	Kjaer and Sørensen (1997)
0.33 ± 0.12	69	No. of pecks	Kjaer and Sørensen (1997)
0.38 ± 0.12	69	No. of bouts	Kjaer and Sørensen (1997)

SELECTION EXPERIMENTS

Group selection has been very effective in reducing the incidence of beak-inflicted injuries in caged hens. The selection criterion, in a study by Craig and Muir (1993), was 'hen days without beak-inflicted injuries' which could be regarded as a combined selection against cannibalism, aggression and feather pecking. Each sire family was held in a multiple-bird cage and selected as a group. After two generations of selection, realized family heritability was estimated to be 0.65 ± 0.13. Mortality decreased from 68% to 9% in generation 3 (Muir, 1996), indicating that a major gene may have been involved, and plumage condition improved (Craig and Muir, 1996).

Divergent selection on individual rate of severe feather pecking for two generations on a base population of a commercial laying hybrid produced high and low feather pecking lines significantly different in level of severe feather pecking in generation 1, but in generation 2 there was no significant difference between lines in any type of pecking (gentle or severe feather pecking and aggressive pecking, Keeling and Wilhelmson, 1997).

At the University of Hohenheim, Germany, strains of laying hens were selected for or against pecking at a target connected to an automated recording system, the 'peck-o-meter' (Bessei *et al*., 1999). This is an electronic device, which measures pecks or pulls to a bundle of feathers or an alternative pecking target (e.g. a bunch of white string) attached to a strain gauge. The founder line was a medium-heavy strain laying brown-shelled eggs. Initially, birds from 64 families were screened. Around 200–300 birds from each line were tested in each generation. Selection over three generations showed the expected change in pecking at the target in the two lines. In generation 2 the levels of pecking to the feather bunch were 34 and 16 bouts/bird/20 min, respectively, in the high and low line. In generation 3 the corresponding levels were 28 and 5 bouts/bird/20 min and the lines therefore appeared to be diverging. The very preliminary estimates of heritability in generations 1, 2 and 3, respectively, were 0.18, 0.22 and 0.26 (Bessei *et al*., 2003, personal communication). With regard to feather pecking, the line selected for a high level of pecking at the feathers of the peck-o-meter showed less feather pecking compared with the line selected for a low level of pecking. This negative phenotypic correlation, estimated to be about –0.30, between pecking at the peck-o-meter and feather pecking is the opposite of the expected relationship according to correlations obtained by Bessei *et al*. (1999). Those results, however, were based on family means and not on individual animals. A possible explanation for this negative correlation could be that pecking at a bunch of feathers might be regarded as pecking an inanimate target. It has been hypothesized that feather pecking is connected more or less specifically with coping strategy, feather-pecking birds predominantly being active copers and non-feather-pecking birds being passive copers (Korte *et al*., 1997; Koolhaas *et al*., 1999). From this it follows that feather-pecking birds will be more intrinsically driven and therefore less motivated to investigate inanimate stimuli, i.e. feather bunches. Conversely, non-feather-pecking birds will be more interested in pecking at feather bunches. In line with this hypothesis, Rodenburg and Koene (2000) found a negative relation between feather pecking and pecking at a bunch of feathers. Therefore, selection might prove to be successful in generating high and low feather-pecking lines, indirectly, and the

average level of feather pecking in the lines will be negatively correlated to the level of pecking recorded by the peck-o-meter.

At the Danish Institute of Agricultural Sciences in Foulum, high and low feather-pecking lines were developed on the basis of a random-bred White Leghorn strain maintained as a control line (C). The selection criterion was based on the number of bouts of feather pecking (with no distinction between gentle or severe pecks) recorded during a 3-h observation session in which hens were kept in littered floor pens in groups of 20, consisting of 10 birds from the high pecking line (HP) and 10 from the low pecking line (LP). Breeding values were calculated using an Animal Model procedure. After three generations of selection, significant differences in feather pecking behaviour and plumage condition were found between the low and the high pecking line (Kjaer *et al*., 2001). The average rate of feather pecking in HP and LP, respectively, was 4.6 versus 0.6 bouts per bird per hour ($P<0.001$) equivalent to 13.9 versus 2.5 pecks per bird per hour ($P<0.001$) and the proportion of hens recorded as feather pecking in a 180-min observation period was 75 versus 49% ($P<0.001$). Estimates of heritability are given in Table 12.4.

Table 12.4. Estimates of heritability of feather pecking based on selected lines.

Heritability ± SE	Generations of selection	Comments	Reference
0.20[a]	3	On combined data from low and high feather-pecking lines	Kjaer *et al.* (2001)
0.18 ± 0.08	5	Low feather-pecking line	Su *et al.* (2003)
0.14 ± 0.07	5	High feather-pecking line	Su *et al.* (2003)
0.65 ± 0.13	2	Feather pecking, cannibalism and aggression in a combined trait	Craig and Muir (1993)

[a]Realized heritability, no SE given.

CORRELATED RESPONSES

Genetic correlations are essential in relation to selective breeding in order to understand the effects of selection on one trait, e.g. feather pecking, and the correlated effect on production and other traits (egg production, sexual maturity, etc.). Due to the statistical methods of calculation, genetic correlations mostly have relatively large standard errors and should be treated accordingly.

It has been assumed in earlier studies on feather pecking that selection for high egg production increases the tendency for feather pecking. This relationship is not very clear-cut, however. Kjaer and Sørensen (1997) found a negative genetic correlation between body weight at 52 weeks and the prevalence of feather pecking. This could indicate that selection for smaller body size, which has occurred in commercial breeding programmes for layers, may have contributed to feather pecking problems. Furthermore, the genetic correlation between feather pecking activity in pullets (average of observations from 6 to 18 weeks) and body weights at 2 days, 8 and 20 weeks were 0.20, 0.66 and 0.57, respectively (Bessei, 1984a). In

contrast to this, selection for and against feather pecking reduced body weight in the low pecking line compared with the high pecking line in generation 3 (Kjaer *et al.*, 2000). Probably the higher body weight was the main cause of higher egg weight and higher egg mass production in the high pecking line. Preliminary, unpublished results for generation 4 showed no difference between lines with regard to body weight at 25 weeks of age. Taken together, further studies are needed in order to make conclusions on this correlation. However, the evidence from the multi-strain experiment suggests that there is little correlation between body weight and feather pecking or cannibalism: the absolute values of the between-breed genetic correlation for body weight and egg numbers, respectively, with feather score, skin lesions and mortality were less than 0.15 and 0.11.

Craig *et al.* (1975) reported an associated increase in feather pecking and cannibalism in White Leghorns selected for early sexual maturity and Muir (1996) found that selection of survivor groups in multiple bird cages decreased mortality very significantly. As selection in individual cages and selection for earlier sexual maturity were introduced in some commercial breeding programmes in the late 1980s, these changed selection practices may represent one of the underlying causes of an apparent increase in the propensity for cannibalism to occur in caged layers. Selection for decreased body weight and residual feed consumption might also be implicated in any rise in the propensity for feather pecking and cannibalism in commercial flocks.

In a recent experiment at DIAS, Foulum, an international commercial hybrid was compared to a Danish commercial hybrid, Hellevad, and the two pure lines of this cross (Kjaer and Sørensen, 2002). The birds were kept in 24 flocks in a small-scale (40 hens per flock) free-range system. The international hybrid birds clearly performed best with regard to egg production, but they also had the highest mortality from cannibalism: 16% versus 0–1.4% in the less productive strains. Nevertheless the local hybrid, Hellevad, is becoming more popular in organic egg production in Denmark, because welfare-related factors, such as an absence of cannibalism and feather pecking, are becoming more important. Five commercial hybrids are under evaluation in the same experimental conditions at the time of writing (J.B. Kjaer and P. Sørensen, unpublished), and the same correlation between productivity and injurious pecking behaviour also appears to exist among these hybrids.

MOLECULAR STUDIES

Biometric studies suggest that the genetic background of feather pecking is polygenic (Kjaer and Sørensen, 1997) whereas cannibalism and aggression combined (beak-inflicted injuries) may be influenced by a major gene (Muir, 1996). New molecular techniques have been applied by a group of researchers in The Netherlands (Buitenhuis *et al.*, 1999) aiming to identify relevant genetic regions or genes that cause differences in feather pecking. Two White Leghorn lines differing in rate of feather pecking, probably due to responses correlated to selection on production parameters (Blokhuis and Beutler, 1992) were the base lines in a two-pronged investigation. A candidate gene and comparative mapping approach addressed specific genes and supplement the main search for quantitative trait loci (QTL) associated with the target behaviour. Based on the suggestion of Korte *et*

al. (1997), the glucocorticoid receptor (GR) gene is a candidate gene. The position of this gene is unknown in the chicken, but the position on human chromosome 5 is known (5q31). The fact that several other genes in this region are known to occur in a specific chicken linkage group, makes this human linkage group a likely candidate for the location of the chicken GR gene. In the complementary QTL analysis, a screening of 180 microsatellite markers on over 600 F_2 birds has been done. Phenotypic recordings on these birds include corticosterone response to manual restraint and observations of feather pecking behaviour in a social test at 6 and 30 weeks of age. Suggestive QTL for gentle feather pecking at 6 and 30 weeks of age were identified and a significant QTL for severe feather pecking at 30 weeks was detected (Buitenhuis *et al*., 2003). The results suggested that feather pecking behaviour at 6 and 30 weeks may be regulated by different genes and, more importantly, that indirect selection to decrease feather pecking and cannibalism by marker-assisted selection may be possible.

In a Swedish study (Jensen *et al*., 2003) no QTL for performing feather pecking were detected in an F_2 population of 751 intercross birds from one Red Jungle Fowl sire and four White Leghorn dams. However, a significant QTL was associated with plumage condition, reflecting exposure to feather pecking, and this QTL coincided with the colour gene 'dominant white'. Animals homozygous for the Jungle Fowl allele had significantly poorer plumage condition.

The validity of the search for QTL associated with a complex behavioural trait such as feather pecking and cannibalism is illustrated by the search for genes for fear and anxiety in laboratory mice (Flint *et al*., 1995). Two lines of mice that differed in several measures of fear were crossed and six QTL for 'open field activity' (a measure of fear) were detected that accounted for all of the additive genetic variation in this trait. The authors concluded that relatively few genes (strictly QTL) acting additively and independently were responsible for the differences in fearfulness between the two lines, the heritability of which was only 0.26.

DISCUSSION

Differences in the rate of feather pecking, quality of plumage and mortality from cannibalism between populations of domestic fowl are well documented. The nature of the genetic background of these differences is less well known. Several studies have addressed this question during the past few decades. There is accumulating evidence supporting the existence of additive genetic effects underlying feather pecking behaviour, with heritability estimates ranging from 0.1 to 0.4. With regard to cannibalistic pecking there is evidence that one or a few major genes may influence the trait. Selection lines differing in the propensity to perform feather pecking or cannibalistic pecking have been developed. Realized heritabilities, respectively of 0.2 to 0.7, have been reported. Correlations between feather pecking behaviour and cannibalistic pecking and traits related to egg production, feed consumption and egg quality need further investigation but are unlikely to be sufficiently high to severely compromise selection for production traits.

One of the major problems of genetic change is the difficulty in measuring the trait: feather pecking and cannibalism are infrequent and their expression is variable even in lines that are predisposed to them. It is also possible that there are a number of genetic behavioural traits that give rise to the same end-point. In

support of this contention, several of the lines in the multi-strain experiment had extensive feather loss with no mortality and vice versa. Other lines suffered high culling rates because of self-pecking at the toes and legs, or pecking at the tail area with no other signs of feather loss or damage. Furthermore, the type of pecking was similar in the two different pens in which each line was represented.

The 'different genetic behaviours' hypothesis of feather pecking and cannibalism is constant with one of the diathesis–stress models of schizophrenia in humans (Meehl (1962), cited in Heinrichs (2001)). One can imagine the existence of one or a few major genes, with low penetration, leading to a developmental disorder of the brain causing vulnerability for the development of feather pecking and cannibalism. These major genes may in turn be influenced by numerous 'moderator' genes as well as by rewards (positive feedback from feather pecking) and punishments (lack of stimulation) from the environment. These 'moderator' genes can, without the existence of the major feather pecking genes but in combination with environmental stress, lead to behavioural disorders that resemble feather pecking from a clinical standpoint but differ in their aetiology and neurogenesis.

These difficulties of trait definition may inhibit the estimation of robust genetic parameters because different behavioural traits that result in the same outcome may be segregating in different populations. These considerations suggest that 'blunt instruments' such as selection in group housing conditions (Muir, 1996) might generally be the most likely to succeed in changing the propensity for feather pecking and cannibalism in commercial flocks of laying hens.

REFERENCES

Abrahamsson, P. and Tauson, R. (1995) Aviary systems and conventional cages for laying hens. *Acta Agriculturae Scandinavica* 45, 191–203.

Allen, J. and Perry, G.C. (1975) Feather pecking and cannibalism in a caged layer flock. *British Poultry Science* 16, 441–451.

Ambrosen, T.A. and Petersen, V.E. (1997) The influence of protein level in the diet on cannibalism and quality of plumage of layers. *Poultry Science* 76, 559–563.

Bessei, W. (1983) Zum Problem des Federpickens und Kannibalismus. *Deutsche Geflügelwirtschaft und Schweinproduktion* 24, 656–665.

Bessei, W. (1984a) Genetische Beziehungen zwischen Leistung, Befiederung und Scheu bei Legehennen. *Archiv für Geflügelkunde* 48, 231–239.

Bessei, W. (1984b) Untersuchungen zur Heritabilität des Federpickverhaltens bei Junghennen. 1. Mitteilung. *Archiv für Geflügelkunde* 48, 224–231.

Bessei, W., Reiter, K., Bley, T. and Zeeb, F. (1999) Measuring pecking of a bunch of feathers in individually housed hens: first results of genetic studies and feeding related reactions. *Lohmann Information* 22, 27–31.

Blokhuis, H.J. and Arkes, J.G. (1984) Some observations on the development of feather pecking in poultry. *Applied Animal Behaviour Science* 12, 145–157.

Blokhuis, H.J. and Beutler, A. (1992) Feather pecking damage and tonic immobility response in two lines of White Leghorn hens. *Journal of Animal Science* 70, 170.

Blokhuis, H.J., Beuving, G. and Rommers, J. (1993) Individual variation of stereotyped pecking in laying hens. In: *Proceedings of the 4th Symposium on Poultry Welfare*, September 18–21, Edinburgh, pp. 19–26.

Buitenhuis, A.J., Crooijmans, R.P.M.A., Bovenhuis, H., Groenen, M.A.M. and Van

der Poel, J.J. (1999) Genetic approaches to identify genes controlling feather pecking behaviour in laying hens. In: *Proceedings of the Poultry Genetics Symposium,* October 6–8, Mariensee, Germany, p. 109.

Buitenhuis, A.J., Rodenburg, T.B., van Hierden, Y.M., Siwek, M., Cornelissen, S.J.B., Nieuwland, M.G.B., Crooijmans, R.P.M., Groenen, M.A.M., Koene, P., Korte, S.M., Bovenhuis, H. and Van der Poel, J.J. (2003) Mapping quantitative trait loci affecting feather pecking behaviour and stress responses in laying hens. *Poultry Science* 82, 1215–1222.

Conson, M. and Petersen, J. (1986) Beurteilung der Gefiederbeschaffenheit unterschiedlich aufgezogener Legehybriden. *Archiv für Geflügelkunde* 50, 159–169.

Craig, J.V. and Muir, W.M. (1989) Fearful and associated responses of caged White Leghorn hens: genetic parameter estimates. *Poultry Science* 68, 1040–1046.

Craig, J.V. and Muir, W.M. (1993) Selection for reduction of beak-inflicted injuries among caged hens. *Poultry Science* 72, 411–420.

Craig, J.V. and Muir, W.M. (1996) Group selection for adaptation to multiple-hen cages: beak-related mortality, feathering, and body weight responses. *Poultry Science* 75, 294–302.

Craig, J.V., Jan, M.L., Pooley, C.R., Bagwat, A.L. and Dayton, A.D. (1975) Changes in relative aggressiveness and social dominance associated with selection for early egg production in chickens. *Poultry Science* 54, 1647–1658.

Craig, J.V., Craig, T.P. and Dayton, A.D. (1983) Fearful behaviour by caged hens of two genetic stocks. *Applied Animal Ethology* 10, 263–273.

Cuthbertson, G.J. (1980) Genetic variation in feather-pecking behaviour. *British Poultry Science* 21, 447–450.

Damme, K. and Pirchner, F. (1984) Genetic differences of feather-loss in layers and effects on production traits. *Archiv für Geflügelkunde* 48, 215–222.

Falconer, D.S. (1989) *Introduction to Quantitative Genetics*. Longman Scientific and Technical, Essex, UK.

Flint, J., Corley, T., DeFries, J.C., Fulker, D.W., Gray, J.A. and Miller, S. (1995) A simple genetic basis for a complex psychological trait in laboratory mice. *Science* 269, 1432–1435.

Flock, D.K. and Heil, G. (2002) A long-term analysis of time trends in the performance profile of white-egg and brown-egg hybrid laying strains based on results of official German random sample tests from 1974/75 to 1997/99. *Archiv für Geflügelkunde* 66, 1–20.

Gentle, M.J. (1986) Neuroma formation following partial beak amputation (beak trimming) in the chicken. *Research in Veterinary Science* 41, 383–385.

Gentle, M.J., Waddington, D., Hunter, L.N. and Jones, R.B. (1990) Behavioural evidence for persistent pain following partial beak amputation in chickens. *Applied Animal Behaviour Science* 27, 149–157.

Gentle, M.J., Hughes, B.O., Fox, A. and Waddington, D. (1997) Behavioural and anatomical consequences of two beak trimming methods in 1- and 10-d-old domestic chicks. *British Poultry Science* 38, 453–463.

Grashorn, M. and Flock, D. (1987) Genetisch-Statistische Untersuchungen des Befiederungszustandes an weißen, LSL, und braunen, LB, Hennen. *Lohmann Informationen* Nov/Dec, 13–19.

Harrison, C.J. (1965) Allopreening as agonistic behaviour. *Behaviour* 24, 161–209.

Heinrichs, R.W. (2001) *In Search of Madness*. Oxford University Press, New York.

Hocking, P.M., Channing, C.E., Robertson, G.W., Edmond, A. and Jones, R.B. (2004) Between-breed genetic variation for welfare-related behavioural traits in domestic fowl. *Applied Animal Behaviour Science* (in press).

Huber-Eicher, B. (1997) An experimental study on the development of feather pecking in domestic chicks (*Gallus gallus domesticus*). *Inauguraldissertation der Philosophisch-naturwissenschaftlichen Fakultät der Universität Bern*, 1–57.

Hughes, B.O. (1973) The effect of implanted gonadal hormones of feather pecking and cannibalism in pullets. *British Poultry Science* 14, 341–348.

Hughes, B.O. and Duncan, I.J.H. (1972) The influence of strain and environmental factors upon feather pecking and cannibalism in fowls. *British Poultry Science* 13, 525–547.

Jensen, P., Keeling, L., Schütz, K., Andersson, L., Kerje, S., Carlborg, Ö. and Jacobsson, L. (2003) *Proceedings of the 37th International Congress ISAE*, Abano Terme, Italy, 24–28 June, p. 68.

Keeling, L. (1995) Feather pecking and cannibalism in layers. *Poultry International*, June, 46–50.

Keeling, L. and Wilhelmson, M. (1997) Selection based on direct observations of feather pecking behaviour in adult laying hens. In: *Proceedings of the 5th Symposium on Poultry Welfare*, Wageningen, 7–10 June, pp. 77–79.

Kjaer, J.B. and Sørensen, P. (1997) Feather pecking in White Leghorn chickens: a genetic study. *British Poultry Science* 38, 333–341.

Kjaer, J.B. and Sørensen, P. (2002) Feather pecking and cannibalism in free-range laying hens as affected by genotype, level of dietary methionine + cystine, light intensity during rearing and age at access to the range area. *Applied Animal Behaviour Science* 76, 21–39.

Kjaer, J.B. and Vestergaard, K.S. (1999) Development of feather pecking in relation to light intensity. *Applied Animal Behaviour Science* 62, 243–254.

Kjaer, J.B., Sørensen, P. and Su, G. (2000) Divergent selection on feather pecking behaviour in laying hens also affects body weight, egg production and egg quality. In: *Abstracts and Proceedings XXI World's Poultry Congress,* August 20–25, Montreal, Canada, P12.07.

Kjaer, J.B., Sørensen, P. and Su, G. (2001) Divergent selection on feather pecking behaviour in laying hens (*Gallus gallus domesticus*). *Applied Animal Behaviour Science* 71, 229–239.

Koolhaas, J.M., Korte, S.M., De Boer, S.F., Van Der Vegt, B.J., Van Reenen, C.G., Hopster, H., Jong, I.C., Ruis, M.A.W. and Blokhuis, H.J. (1999) Coping styles in animals: current status in behaviour and stress-physiology. *Neuroscience and Biobehavioral Reviews* 23, 925–935.

Korte, S.M., Beuving, G., Ruesink, W. and Blokhuis, H.J. (1997) Plasma catecholamine and corticosterone levels during manual restraint in chickens form a high and low feather pecking line of laying hens. *Physiology and Behaviour* 62, 437–441.

Kruijt, J.P. (1964) Ontogeny of social behaviour in Burmese red junglefowl, *Gallus gallus spadiceus*. *Behaviour Supplements* 12, 201 pp.

Madsen, H. (1966) On feather picking and cannibalism in pheasant and partridge chicks, particularly in relation to the amino acid arginine. *Acta Veterinaria Scandinavica* 7, 272–287.

McAdie, T.M. and Keeling, L.J. (1999) Effect of manipulating feathers of laying hens on the incidence of feather pecking and cannibalism. In: *Proceedings of the Nordic ISAE Winter meeting*, Flämslätt, Sweden.

Meehl, P.E. (1962) Schizotaxia, schizotypy, schizophrenia. *American Psychologist* 17, 827–838.

Muir, W.M. (1996) Group selection for adaptation to multiple-hen cages: selection program and direct responses. *Poultry Science* 75, 447–458.

Neal, M.W. (1956) Cannibalism, pick-outs and methionine. *Poultry Science* 35, 10–13.

Ouart, M.D. and Adams, A.W. (1982) Effects of cage design and bird density on layers. 1. Productivity, feathering and nervousness. *Poultry Science* 61, 1606–1613.

Richter, F. (1954) Experiments to ascertain the causes of feather-eating in the domestic fowl. In: *10th World's Poultry Congress*, Edinburgh, pp. 258–262.

Rodenburg, T.B. and Koene, P. (2000) Feather pecking and coping style in the laying hen. In: *Feather Pecking in Laying Hens: Exploring Solutions. Proceedings of Meeting*, 21 June, University of Bristol,.

Savory, C.J. (1995) Feather pecking and cannibalism. *World's Poultry Science Journal* 51, 215–219.

Savory, C.J. and Mann, J.S. (1997) Behavioural development in groups of pen-housed pullets in relation to genetic strain, age and food form. *British Poultry Science* 38, 38–47.

Su, G., Kjaer, J.B. and Sørensen, P. (2003) Genetic improvement on feather pecking behaviour is effective. In: *Proceedings of the 3rd European Poultry Genetics Symposium*, 17–19 September, Wageningen, The Netherlands.

Tauson, R., Elwinger, K. and Ambrosen, T. (1984) Evaluation of procedures for scoring the integument of laying hens: independent scoring of plumage condition. *Acta Agriculturae Scandinavica* 34, 400–408.

Tind, E. (1985) Feather loss: the effects of abrasion. In: *Proceedings 2nd European Poultry Welfare Symposium,* 10–13 June, Celle, pp. 190–200.

Tind, E. and Ambrosen, T. (1988) Egg layers in cages: effects of cage shape, group size and density. *Report from the National Institute of Animal Science, Denmark*, No. 643 (in Danish with English summary and subtitles).

Wechsler, B., Huber-Eicher, B. and Nash, D.R. (1998) Feather pecking in growers: a study with individually marked birds. *British Poultry Science* 39, 178–185.

Wennrich, G. (1975) Studien zum Verhalten verschiedener Hybrid-Herkünfte von Haushühnern, *Gallus domesticus*, in Bodenintensivhaltung mit besonderer Berücksichtigung aggressiven Verhaltens sowie des Federpickens und des Kannibalismus. 5. Mitteilung: Verhaltensweisen des Federpickens. *Archiv für Geflügelkunde* 39, 37–44.

CHAPTER 13
Breeding for productivity and welfare of laying hens

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ABSTRACT

Over the past five decades the art of animal breeding has rapidly advanced into an exacting science including such advanced tools as Best Linear Unbiased Prediction (BLUP) and Restricted Maximum Likelihood (REML) estimation of variance components. Unfortunately, in most selection programmes only traits directly related to productivity are considered and, as a result, those breeding programmes ignore traits that impact on animal welfare. The consequences of ignoring animal welfare in breeding programmes are threefold: (i) if higher-producing animals tend to be more competitive, then the effect of selection is to increase competition, which worsens the animals' welfare; (ii) increased competition has the effect of lowering productivity of other animals that are in direct contention, thus resulting in reduced (or negative) gains for productivity; and (iii) genotype–genotype interaction (competition) invalidates the traditional BLUP animal model and negates many advantages of this technology and could in fact make it a liability. This chapter reviews recent advances that allow selection on production traits but take into account competitive interactions. Those advances fall into two categories: (i) group selection and (ii) advanced mixed models with a second random effect for indirect genetic effects (competition). Both methods have been verified in poultry breeding applications and have resulted in dramatic improvements in livability, productivity and welfare.

INTRODUCTION

Historically, animal well-being issues were not considered in breeding programmes for a number of reasons. From a practical standpoint, nearly every trait that has ever been selected for shows some genetic variability and response to selection. However, breeders are careful to minimize the number of traits in a breeding programme because each additional trait added to the selection objective dilutes the selection intensity on the primary trait. Thus, in order to convince breeders to include animal well-being in section programmes, there needs to be an economic incentive.

Over the course of the past 20 years, research has shown that alternative methods of selection are possible which increase both productivity and animal well-

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being without measuring any new traits. As such, the methods benefit both the producer and the animal. Because the methods improve well-being as a by-product, they are indirect. This chapter reviews the state of the art of selection programmes that indirectly improve animal well-being. In addition to productivity and mortality, it will also examine correlated physiological changes in the bird to support these conclusions.

GROUP SELECTION

Group selection is an indirect method of selection that benefits the group. Group selection was first hypothesized as a mechanism of evolution to account for altruistic behaviour. However, the term 'group selection' has many different meanings and has sparked numerous debates. In the 1960s 'group selection rivalled Lamarkianism as the most thoroughly repudiated idea in evolutionary theory' (Wilson, 1983). Later experiments with laboratory insects clearly showed the power of group selection to improve survival (Wade, 1976, 1977, 1978; McCauley and Wade, 1980; Wade and McCauley, 1980; Craig, 1982). The entire controversy is partly a matter of semantics. What some call group selection is really selection among individuals for those who benefit the group (Individual–Group or I:G). What others call group selection is selection among groups, where the entire group is selected or culled based on the performance of the group as a whole (Group–Group or G:G). The controversy stems from I:G selection or, as Wilson (1983) states,

> … if natural selection favors individuals that leave the most offspring, then individuals that benefit themselves at the expense of others should be very fit indeed. Individuals that benefit others, presumably at some expense to themselves, would be selected against as surely as if they had bad eyes or faulty teeth.

Hence I:G selection is problematic from a theoretical perspective. On the other hand, G:G selection requires that natural populations be subdivided into groups such that selection could be among those groups. Controversy persists because group-level adaptations require natural selection among alternative groups, but natural selection within groups will be opposed to that level of selection (Williams, 1966). Which force is stronger is still a subject of debate. Further controversy exists as to whether such grouping really occurs in nature, given that migration frequently occurs between groups (Wilson, 1983).

Nevertheless, it is clear to all that group-level adaptations require a higher level of selection than that among individuals. How group selection occurs in nature is a matter for debate and of academic interest, but in an agricultural setting the breeder can establish the groups (pens or cages), minimize mixing between groups, and selection can be based on the group mean. Of greater importance is that behaviour is a group-level adaptation, which means that it is impossible to improve behaviour at the individual level without directly selecting for behaviour traits, i.e. selection for increased individual productivity only maximizes individual productivity, not necessarily that of the group.

The quantitative relationship between individual and group productivity was first presented by Griffing (1967) when he extended classic population genetic models to include competitive effects. Griffing (1967) recognized that with

competition, the usual gene model for a given genotype must be extended to include not only the direct effects of its own genes, but also the associated contributions from other genotypes in the group. Griffing (1967) termed the associated effect of one plant on another as the 'associative' effect of that plant; in animals the associative effect is generally referred to as being due to competition, competition being for either limited food or space, or for social status (pecking order). Thus, in theoretical treatments of the subject, the conceptual biological model must first be extended to define the group and, second, the usual gene model must be extended to include not only the direct effect of the individual's own genes, but also associated contributions from other genotypes in the group.

Griffing (1967) showed that in the presence of interacting genotypes, the expected change in the mean ($\Delta\mu$) from individual selection of intensity *i* in a population with a phenotypic standard deviation of σ is

$$\Delta\mu = \left(i/\sigma\right)\left[{}_{d}\sigma_A^2 + {}_{(da)}\sigma_A\right]$$

where ${}_{d}\sigma_A^2$ is the additive variance of the direct effects and ${}_{(da)}\sigma_A$ is the additive covariance between direct and associative effects. If the covariance is negative, as occurs when there is competition for a limited resource, then selection based on individual performance can have a reverse effect on the mean; i.e. positive selection will reduce rather than increase the mean. This results because a gene that has a positive direct advantage for the individual has a negative associate effect on the group. These results are contrary to those predicted by classic quantitative genetics, but verify Williams' (1966) conclusion that individual selection can oppose productivity of the group. In contrast, if the group is defined as the unit selection, then

$$\Delta\mu = \left(i/\sigma\right)\left[{}_{d}\sigma_A^2 + {}_{(da)}\sigma_A^2 + {}_{a}\sigma_A^2\right]$$

where ${}_{a}\sigma_A^2$ is the additive variance for associative effects. In this case, because all the individual terms are squared, $\Delta\mu$ is always positive. Thus, transferring selection from the individual to the group ensures that the population mean will not decrease.

Griffing (1967) also showed that with group selection, it is possible to select for an allele that has a negative direct effect but positive associative effect, i.e. altruistic or self-sacrificing traits. This conclusion also supports the notion that adaptability at the group level requires selection on a different unit of selection; that of the group rather than the individual.

Griffing (1967) further notes that as group size increases, associate effects take on an increasingly dominant role in determining the consequences of selection, and implies that as cage or pen size increases, group performance is dominated by associative effects, rather than direct effects. For a breeding programme, this means that in large group sizes, more response may be achieved by reducing competitive effects than by selecting for direct effects.

These theories also extend to among-family-group selection. Griffing (1976) showed that the efficiency of group selection is greatly increased if the group is composed of related individuals, particularly as group size increases. This form of family selection should not be confused with traditional family selection. In order to clarify this issue, a distinction needs to be made based on what information is used to determine the genetic merit of an animal, and how those individuals are

housed. With traditional family selection, as defined by Falconer (1981), individuals are housed either *singly* or in *random groups*. In some species, such as swine, maternal effects are recognized as an important source of confounding between individual merit and maternal environment, and requires within-family selection to remove the effect, while for other traits where the heritability is low, such as fertility, between-family selection on sire family averages is used to increase the heritability of the trait. Clearly both sources of information are useful, but of different value under alternative situations depending on the heritability of the trait and the importance of permanent environmental effects, and an 'optimal' index is usually used to weight individual versus family information. However, the index is developed by assuming individuals do not interact, i.e. that the index maximizes gain for individual performance, not that of the group. Extension of family selection to include information from all relatives leads to development of Best Linear Unbiased Prediction (BLUP), but suffers from the same limitations as traditional family selection and will be discussed later in the chapter.

EXPERIMENTAL EXAMINATION OF GROUP SELECTION IN POULTRY

The first successful experiment with group selection in poultry or any organisms other than insects was initiated in 1981 using a synthetic line of White Leghorns (Craig and Muir, 1996a,b; Muir, 1996, 2003b; Muir and Craig, 1998). With this procedure, each sire family was housed as a group in a multiple-bird cage and selected or rejected as a group. In the first two generations group size was 9 (413 cm^2 per bird) while in the next four (G3, G4, G5 and G6) group size was 12 (362 cm^2 per bird). Beaks were not trimmed and lighting was at a high intensity so as to allow expression of genetic variation for aggression, feather pecking and cannibalism. Production was measured to 60 weeks of age in the first four generations and to 72 weeks in the last two. The criterion of selection was initially egg mass (EM), which was computed as the product of eggs per hen housed (EHH) and egg weight (EWT). In later generations an index giving equal weight to eggs per hen per day (EHD) and days survival (DS) was used.

Muir (1996) reported that, after six generations, in comparison with the unselected control (C), annual percentage mortality of the selected line (Kinder Gentler Bird, KGB) in multiple-bird cages decreased from 68% in the initial generation to 8.8% in the sixth generation (Fig. 13.1). Percentage mortality in the sixth generation of the selected line in multiple-bird cages was similar to that of the non-selected control in single-bird cages (9.1%). The dramatic improvement in livability demonstrates that adaptability and well-being of these birds were improved by group selection. The similar survival of the selected line in multiple-bird cages and the control in single-bird cages suggests that beak trimming of the selected line would not further reduce mortalities, which implies that group selection can eliminate the need to beak trim. Corresponding improvements in eggs per hen housed (Fig. 13.2) demonstrated that such changes can also be profitable.

Craig and Muir (1996a) compared the selected and control lines to a commercial line, Dekalb XL (DXL), in generation 7 that were housed in either single- or 12-bird cages. Performance was measured from 20 to 58 weeks of age. In single-bird cages, as expected, the DXL commercial bird significantly exceeded the

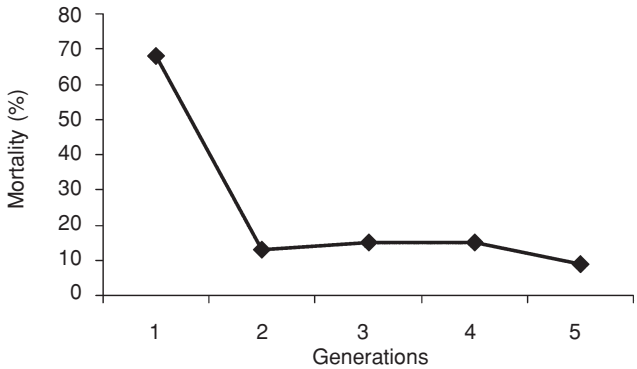

Fig. 13.1. Percentage mortality in colony cages in each generation of selection.

KGB and control lines in terms of eggs per hen housed, eggs per hen per day, egg weight and egg mass. However, in 12-bird cages the reverse was seen, with the KGB line superior to the DXL and control line for these same traits. These results demonstrate a classic genotype–environment interaction. Such interactions are predicted by the theories of Griffing (1967) and the arguments of Williams (1966), whereby group adaptations require group selection and individual adaptations will be opposed to those of the group.

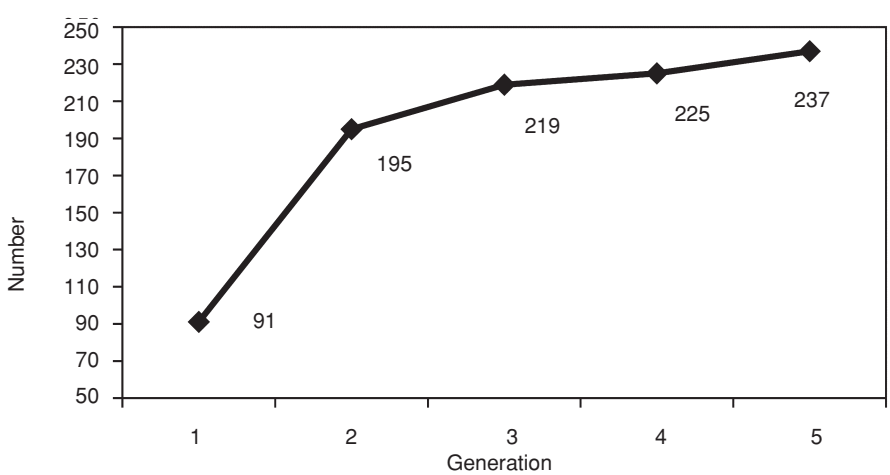

Fig. 13.2. Eggs per hen housed for the group-selected (KGB) chickens.

The most remarkable difference was for mortality (Fig. 13.3). By the termination of the experiment, the DXL line had 89% mortality at 58 weeks of age as compared to the KGB line with 20% and C with 54%. The comparison to the DXL line is particularly important because this line constituted one of the resources used

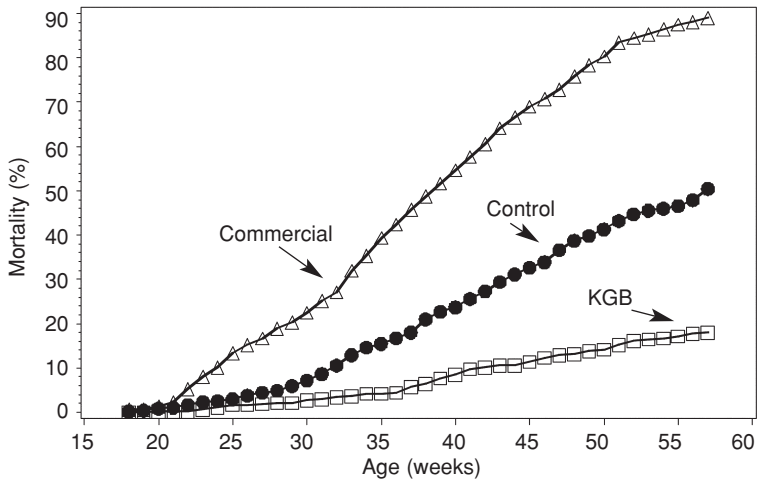

Fig. 13.3. Percentage mortality of the commercial, control and KGB chickens.

to establish the control line from which the KGB was established. The DXL line was the result of continued selection for improved productivity based on individual bird performance. While the comparison is not exact, productivity and survival in relation to the control line demonstrates that continued selection on individual productivity will improve productivity when competitive interactions are absent, as in a single-bird cage, but can result in a negative response to selection in a group setting. These results clearly demonstrate that continued selection based on individual bird productivity is antagonistic to the well-being of the laying hen.

CORRELATED PHYSIOLOGICAL AND BEHAVIOURAL RESPONSE TO GROUP SELECTION

Following 52 weeks of housing in colony cages, Craig and Muir (1996a) observed that the KGB line had significantly better feather score than either control or commercial lines. Observations of hens' agonistic activity in the 12-bird home cage environment revealed that the KGB stock had fewer agonistic acts than the control stock from which it was derived, and both control and KGB lines had less agonistic activity than the commercial stock. These results clearly demonstrated that group selection at the family level turns 'survival of the fittest' emphasized on the individual to 'survival of the adequate' emphasized on the group, by which antisocial behaviours are overcome.

Hester *et al*. (1996a) showed that the KGB line had a lower blood packed cell volume (PCV) and a lower heterophil: lymphocyte (H:L) ratio than either the control or DXL lines in response to handling, transportation and re-caging (Table 13.1). Both PCV and ratio of H:L have been used as stress indicators in animals including chickens (Gross and Siegel, 1983; Maxwell, 1993; Woolaston *et al*., 1996; Hohenhaus *et al*., 1998). Compared to the control and DXL lines, KGB

Table 13.1. Selection-related alterations of haematological parameters and physical index of hens in response to social or heat stress

	Haematological parameters*				Physical index	
Group	PCV (%)	H (%)	L (%)	H/Lratio (%)	Mortality# (%)	Egg production+ (%)
KGB	100.0	103.3	103.0	105.1[a]	9.7[a]	75.3[a]
Control	101.4	121.1	102.1	130.8[b]	17.4[c]	63.9[c]
DXL	102.1	124.2	109.0	136.9[c]	15.3[b]	70.3[b]

*Data were presented as percentage of mean of 12-bird cage/single-bird cage at 33 weeks of age.
Data were collected from hens maintained in 12-bird cages at 44 weeks of age after heat stress.
+ Data were present as percentage of hen-day egg production after/before heat stress from 12-bird cages.
[a, b, c] Means within a row with no common superscript differ significantly.
PCV, packed cell volume; H, heterophil; L, lymphocyte; DXL, Dekalb XL commercial chicken line (see Hester *et al.*, 1996a–c).

line also had better coping capability to cold and heat stressors with a higher productivity and lower mortality (Table 13.1; Hester *et al.*, 1996b,c). These results demonstrated that selection has created lines with different phenotypes, each of which has unique characteristics in physical indices, behavioural style and resistance to stressors. The unique line's characteristics could account for selection-induced differential plasticity of the physiological buffering systems, including the neuroendocrine and immunological systems.

Animal behaviour, including agonistic activity, is controlled by both internal and external factors. Internal factors are mainly neuroendocrine and immunological events. In humans and rodents, abnormal regulation of biogenic amines and hormones, such as catecholamines (dopamine, DA; epinephrine, EP; and norepinephrine, NE), corticosterone (CORT) or their derivatives, have been associated with abnormal behaviour (Bell and Hepper, 1987; Popova *et al.*, 1997; Berman and Coccaro, 1998), change in coping capability (Driscoll *et al.*, 1998) and altered reproduction (Sirotkin and Schaeffer, 1997). Concentrations of DA, EP and NE, as well as the ratio of EP:NE, have been used as indicators of the organism's well-being and ability to cope with stress (Dillon *et al.*, 1992; Bell and Hobson, 1994; Popova *et al.*, 1997). In addition, changes in neuroendocrine homeostasis may result in immunosuppression that then affects the animals' survivability and productivity (Dohms and Metz, 1991). Several immune parameters have been used as indicators to evaluate animals' immunity, such as ratio of $CD4^+$:$CD8^+$ T cells (Levinson and Jawetz, 1996), or capability to respond to stress, such as heterophil: lymphocyte ratio (Gross and Siegel, 1983) and numbers of circulating eosinophils (Malyshev *et al.*, 1993).

The functions of the avian neuroendocrine and immune systems in response to stimulation are analogous to those in humans and rodents (Covelli *et al.*, 1981; Harvey *et al.*, 1984; Wambebe, 1986). In addition, there are similar distributions of neurotransmitter receptors, such as DA, in avian and mammal species (Richfield *et al.*, 1987; Ferrari and Giuliani, 1993; Cardinaud *et al.*, 1997; Dietl and Palacios, 1998; Jiao *et al.*, 2000). As in mammals, there are measurable changes in the neuroendocrine and immunological systems in response to stress. These

changes can be used as physiological indicator(s) of an animal's well-being and as guideline(s) in selections of animals with greater resistance to stress.

In order to examine the molecular and cellular mechanism(s) underlying selection-related behavioural and neuroendocrine plasticity, a reverse selected line (MBB) was developed (Cheng *et al.*, 2001a–c). To establish the MBB line, after 52 weeks of production, hens from 12 cages (total 144 hens) with the lowest group productivity and the highest mortality, along with their full- and half-sib brothers, were selected. The 9th generation birds of the KGB line and MBB lines were housed in 12 bird cages, and performance was measured from 20 to 58 weeks of age. The KGB line, as expected, had higher productivity and survivability than the MBB line (Table 13.2; Cheng *et al.*, 2001b). The remarkable differences in productivity and survivability between KGB and MBB lines provide an effective model with which to examine the effect of genotype–environment interactions on animal well-being.

Table 13.2. Selection-induced alterations in the productivity and survivability in hens.

Trait	KGB line	MBB line
Mortality (%)	$1.3^{b} \pm 0.1$	$8.6^{a} \pm 0.5$
Longevity (days)	$363^{b} \pm 0.4$	$193^{a} \pm 21$
Egg number per hen	$295^{b} \pm 11$	$108^{a} \pm 12$
Egg mass per hen (g/day)	$48^{b} \pm 2$	$17^{a} \pm 1.8$
Egg weight (g)	$59.4^{a} \pm 0.6$	$58.9^{a} \pm 0.8$

[a,b] Means within a row with no common superscript differ significantly ($P < 0.05$).

Cheng *et al.* (2001a) first compared the KGB and MBB lines housed in single-bird cages (542 cm^2/bird). At 21 weeks of ages, the KGB line had higher percentages of blood lymphocytes and $CD4^+$:$CD8^+$ ratio of circulating T cells (1.9 vs. 1.1; Table 13.3). The normal ratio of $CD4^+$:$CD8^+$ T cells should be higher than 1.5, otherwise cellular immune mechanisms are greatly impaired and survivability is damaged (Levinson and Jawetz, 1996). Compared to the MBB line, the KGB line may have a more efficient cell-mediated immunity, as the percentage of several cell types involved in the cell-mediated immunity also tended to be greater in the KGB line, such as monocytes (124%) and γδ T cells (131%) (Table 13.4). In

Table 13.3. Selection-induced alterations in the subpopulations of T cells in the hens.

Group	$CD4^+$ cells (% positive)	$CD8^+$ cells (% positive)	$CD4^+$:$CD8^+$ (ratio)	γδ cells (% positive)
KGB	33.0 ± 2.1	$18.2^{b} \pm 1.8$	1.9^{a}	16.1 ± 2.1
MBB	29.3 ± 3.3	$25.8^{a} \pm 1.5$	1.1^{b}	12.2 ± 2.8
KGB:MBB	113%	71%	173%	131%

[a, b] Means within a column with no common superscript differ significantly ($P < 0.01$).

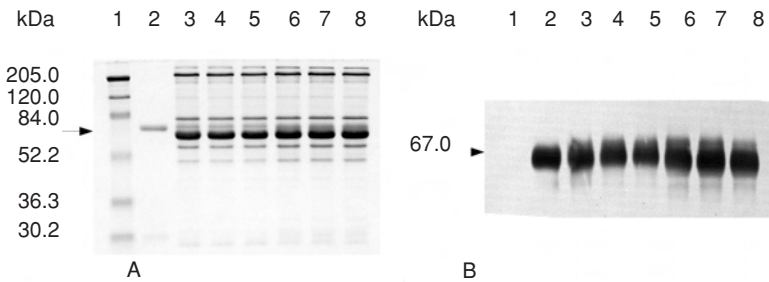

Fig. 13.4. Quantitative analysis of chicken IgG on SDS-PAGE gel electrophoresis. (A) separated proteins on the gels were stained with Coomassie blue, and (B) separated protein on the gels were detected by Western blot analysis plus enhanced chemiluminescence. *Lane 1*, prestained broad-range molecular weight marker; *Lane 2*, commercial chicken IgG; *Lanes 3–5*, samples from KGB hens; *Lanes 6–8*, samples from MBB hens. Note that the band from the samples was identical with the band prepared with commercial chicken IgG, and the size of IgG was identified approximately at 67 kDa (arrow).

addition, the KGB line had a lower H:L ratio and lower numbers of circulating eosinophils. In contrast, MBB hens had higher concentrations of plasma IgG (Fig. 13.4). The negative correlation between total IgG concentrations and productivity and survivability has been found in other studies using various chicken strains (Siegel and Gross, 1980; Siegel *et al*., 1982; Gross and Siegel, 1988) and in other species, such as rodents (Ozherelkov *et al*., 1985) and dairy cattle (Detilleux *et al*., 1991; Weigel *et al*., 1992). The present and previous results suggest that selection for productivity and survivability also alters the immunological and haematological systems. The improved immunity may indicate that the KGB line has greater adaptive capability to stress than the MBB line. This hypothesis is consistent with the results of Craig and Muir (1996a,b), who showed that the KGB line exhibited better feather score, lower mortality and higher reproduction in a socially crowded environment.

Table 13.4. Selection-induced alterations in the differential leucocyte counts in the hens.

Line	Heterophils (H)	Lymphocytes (L)	H:L ratio (×100)	Monocytes	Eosinophils	Basophils
KGB	$10.7^{b} \pm 1.13$	$83.4^{a} \pm 1.3$	13.0b	2.6 ± 0.4	$1.7^{b} \pm 0.2$	1.6 ± 1.1
MBB	$20.4^{a} \pm 1.8$	$72.3^{b} \pm 1.8$	29.4a	2.1 ± 0.4	$3.8^{a} \pm 0.4$	1.4 ± 0.2
KGB: MBB	53%	115%	44%	124%	45%	114%

[a, b] Means within a column with no common superscript differ significantly ($P < 0.01$).

Cheng *et al*. (2001b) also showed that, in the single-bird cage, the KGB line had significantly lower blood concentrations of DA and EP as well as a lower ratio of EP:NE (Table 13.5). Compared to the MBB line, the lower concentrations of catecholamines in the KGB line could be associated with sedate and passive behaviours (Craig and Muir, 1996a,b), and related to better and quicker adaptation to

Table 13.5. Selection-induced alterations in blood concentrations of catecholamines in hens.

Group	Dopamine (ng/ml)	Epinephrine (EP) (ng/ml)	Norepinephrine (NE) (ng/ml)	EP:NE (%)
KGB	0.59 ± 0.08[a]	0.30 ± 0.06[a]	0.86 ± 0.12	34.0[a]
MBB	2.42 ± 0.76[b]	0.59 ± 0.13[b]	0.84 ± 0.13	72.5[b]
KGB: MBB	24.4%	50.8%	102.3%	46.9%

[a,b] Means within a column with different superscript are statistically different ($P < 0.01$).

various stressors in caged production systems (Hester *et al.*, 1996a,b). Furthermore, the high blood concentrations of DA in the MBB line with lower productivity are consistent with the hypothesis that the dopaminergic system is one of the main inhibitory neuronal systems that controls the development of the reproductive systems (Becu-Villalobos and Libertun, 1995) and productivity (Sotowska-Brochocka *et al.*, 1994).

Similar findings to the present conclusions are found in at least two other studies. Higher concentrations of DA were found in Japanese quail that exhibited aggressive behaviour (Edens, 1987), and an upregulation of EP concentration was found in turkeys that were selected for higher adrenal response to cold stress (HL line) (Brown and Nestor, 1974). Turkeys of the HL line also laid significantly fewer eggs and were hyperactive, as was the case in the MBB line. Based on the present and previous observations, the selection-induced differences in the concentrations of catecholamines, survivability and productivity could be interpreted as evidence that coping strategies of the selected strains are based on an inheritance basis and phenotypic correlations of behavioural, physiological and neuroendocrine variables. In the present strains, selection may directly or indirectly influence regulation of the neuroendocrine system, resulting in better survival behaviour and productive performance in the KGB line.

Compared to the MBB line, the KGB line tended to have greater concentrations of corticosterone (CORT) in single-bird cages (1.87 vs. 1.49 ng/ml, P=0.08; Cheng *et al.*, 2001a). The upregulation of CORT in the KGB line is consistent with previous findings that the KGB hens had greater adrenal weights compared to those of the control line (Hester *et al.*, 1996a) and could indicate that they have a hyperactive CORT system. Alternatively, the KGB bird, being adapted to a multiple-bird environment, could be stressed in single-bird cages, and is better adapted to multiple-bird cages. Cheng *et al.* (2003a, and unpublished results) compared measures of stress in one-, four- and ten-bird cages and found that the order of stressors, from least to most, was four-, one- and then ten-bird. In general, chickens are social animals, and the results are consistent with the conclusion that they prefer an environment that consists of small group sizes.

The changes of the adrenal system of the KGB line could also be a part of defence mechanisms permitting animals to remain alert and keep physiological homeostasis in response to environmental challenges, which may underlie their better capability to cope with social, handling and environmental stressors (Craig and Muir, 1996a,b; Hester *et al.*, 1996a,b). A tendency for greater concentrations of CORT could also be related to the KGB hens' higher productivity (Muir and Craig, 1998; Cheng *et al.*, 2001b). Previous studies have reported that the effects

of CORT on productivity could be involved in regulating ovarian function (Etches *et al*., 1984; Lang *et al*., 1984) and/or controlling ingestion and metabolism (Tempel and Leibowitz, 1994).

Cheng *et al*. (2003a,b) further reported there were strain-specific interactions between hierarchies and environmental effects in response to various social stressors between the selected lines. In the ten-bird cages, a crowded social environment, the KGB line had lower levels of plasma DA and heavier adrenal glands than those of the MBB line, but concentrations of CORT from the two lines were not significantly different (Table 13.6). Similar to the current findings, Hester *et al*. (1996a) reported that KGB hens had hypertropic adrenal glands compared to the control and DXL hens. When paired with DXL hens, an aggressive competitor, the MBB line had significantly higher concentrations of CORT than the KGB line (Table 13.6; Cheng *et al*., 2002). These results further suggested that maintenance in a crowded social environment, or social encounters with aggressive competitors, were physiologically more stressful in the MBB than KGB line.

Table 13.6. Effect of genetic–environmental interactions on plasma dopamine and corticosterone concentrations in laying hens.

	Ten-bird cages			Paired with a DXL hen
Treatment	CORT (ng/ml)	AGW (mg/kg of BW)	DA (ng/ml)	CORT (ng/ml)
KGB	10.4 ± 1.7	5.2 ± 0.2[a]	0.15 ± 0.09[a]	6.5 ± 0.8[a]
MBB	9.2 ± 1.4	4.7 ± 0.2[b]	0.44 ± 0.16[b]	11.3 ± 1.5[b]

[a ,b, c] Means within a column with different superscript were statistically different ($P < 0.05$)

Collectively, these results indicate that selection for group productivity and survivability with reduced cannibalism and flightiness alters the regulation of the neuroendocrine and immune systems in maintaining behavioural and physiological homeostasis. The differential functions of the neuroendocrine and immune systems are correlated with the line's unique coping ability to caging environments and resistance to stressors. The KGB hens, in contrast to the MBB hens, could re-establish a peaceful social order after re-caging. These data further suggest that group selection is a useful method and that its adoption in the poultry industry will result in improved livability, productivity and welfare.

ADVANCED MIXED MODEL METHOD TO IMPROVE WELL-BEING

Having concluded that it is impossible to improve the well-being of animals based on individual performance without directly selecting for behaviour traits, we will now show that this goal is possible without measuring behaviour. We will take advantage of the fact that aggressive and competitive behaviour is reflected in the performance of other animals, i.e. those at the bottom of the pecking order have poorer productivity and suffer higher mortality. In this way the impact of one bird on others can be measured indirectly from the performance of the cage mates.

Using this indirect estimate of the impact on other birds (termed associative effects by Griffing (1976)) it is possible to use a selection index with the goal of improving the productivity of the group. The essential feature is that a second random effect is incorporated into the mixed model equations to account for the associative effects of cage mates as well as the usual direct effects of the animal's own genes (Muir and Schinckel, 2002). One can therefore select on behaviour traits without actually measuring those traits, i.e. the associative effects are a result of competition and behaviour.

The efficacy of the method was tested using Japanese quail. The quail were selected for 6-week weight based on either standard Animal Model Best Linear Unbiased Prediction (AM-BLUP), or one incorporating Competitive Effects (CE-BLUP), for 28 cycles (hatches). Results showed that using AM-BLUP failed to yield any response to selection and actually had a negative, but non-significant, trend. In contrast, CE-BLUP gave positive results with significant genetic gains. The lack of response to AM-BLUP was a result of a negative correlated response of associated effects, indicating an increase in competitive effects. Selection based on CE-BLUP increased direct, while reducing associative, effects.

AM-BLUP is considered to be state-of-the-art in animal breeding, but the failure of this method to realize any gain, and reduce viability clearly shows that the method is deficient. AM-BLUP is deficient because it fails to account for genotype–genotype interactions (competition) and invalidates the traditional BLUP animal model, negating the advantages of this technology, and making it a potential liability. As seen from the quail experiment, the solution is simply to expand the model to include associative effects. Unfortunately this solution will only help if individual productivity can be measured, as with growth traits in broilers, or individual egg production using trap nests in layers. For layers in colony cages, identification of which bird produced which eggs cannot be determined and group selection is the only alternative in this system.

REFERENCES

Becu-Villalobos, D. and Libertun, C. (1995) Development of gonadotropin-releasing hormone (GnRH) neuron regulation in the female rat. *Cellular and Molecular Neurobiology* 15, 165–176.

Bell, R. and Hepper, P.G. (1987) Catecholamines and aggression in animals. *Behavioural Brain Research* 23, 1–21.

Bell, R. and Hobson, H. (1994) 5-HT1A receptor influences on rodent social and agonistic behavior: a review and empirical study. *Neuroscience and Biobehavioural Reviews* 18, 325–338.

Berman, M.E. and Coccaro, E.F. (1998) Neurobiologic correlates of violence: relevance to criminal responsibility. *Behavioural Sciences and the Law* 16, 303–318.

Brown, K.I. and Nestor, K.E. (1974) Implications of selection for high and low adrenal response to stress. *Poultry Science* 53, 1297–1306.

Cardinaud, B., Sugamori, K.S., Coudouel, S., Vincent, J.B., Niznik, H.B. and Vernier, P. (1997) Early emergence of three dopamine D1 receptor subtypes in vertebrates: molecular phylogenetic, pharmacological, and functional criteria defining D1A, D1B, and D1C receptors in European eel *Anguilla anguilla*. *Journal of Biological Chemistry* 272, 2778–2787.

Cheng, H.W., Dillworth, G., Singleton, P., Chen, Y. and Muir, W.M. (2001a) Effect of genetic selection for productivity and longevity on blood concentrations of serotonin, catecholamine and corticosterone of chickens. *Poultry Science* 80, 1278–1285.

Cheng, H.W., Eicher, S.D., Chen, Y., Singleton, P. and Muir, W.M. (2001b) Effect of genetic selection for group productivity and longevity on immunological and hematological parameters of chickens. *Poultry Science* 80, 1079–1086.

Cheng, H.W., Eicher, S.D., Chen, Y., Singleton, P. and Muir, W.M. (2001c) Physiological indicators of birds' well-being related to genetic selection for adaptability to caged production systems. In: *Proceedings of the Symposium on Animal Welfare Considerations in Livestock Housing Systems,* pp. 325–334.

Cheng, H.W., Singleton, P. and Muir, W.M. (2002) Social stress in laying hens: differential dopamine and corticosterone responses following intermingling of different genetic strain chickens. *Poultry Science* 81, 1265–1272.

Cheng, H.W., Singleton, P. and Muir, W.M. (2003a) Social stress differentially regulates neuroendocrine responses in laying hens. I. Genetic basis of dopamine responses under three different social conditions. *Psychoneuroendocrinology* 28, 597–611.

Cheng, H.W., Singleton, P. and Muir, W.M. (2003b) Social stress in laying hens: differential effect of stress on plasma dopamine concentrations and adrenal function in genetically selected chickens. *Poultry Science* 82, 192–198.

Covelli, V., Memo, M., Spano, P.F. and Trabucchi, M. (1981) Characterization of dopamine receptors in various species of invertebrates and vertebrates. *Neuroscience* 6, 2077–2079.

Craig, D.M. (1982) Group selection vs. individual selection: an experimental analysis. *Evolution* 36, 271–282.

Craig, J.V. and Muir, W.M. (1996a) Group selection for adaptation to multiple-hen cages: beak-related mortality, feathering and body weight responses. *Poultry Science* 75, 294–302.

Craig, J.V. and Muir, W.M. (1996b) Group selection for adaptation to multiple-hen cages: behavioral responses. *Poultry Science* 75, 1145–1155.

Detilleux, J.C., Freeman, A.E. and Miller, L.D. (1991) Comparison of natural transmission of bovine leukemia virus in Holstein cows of two genetic lines selected for high and average milk production. *American Journal of Veterinary Research* 52, 1551–1555.

Dietl, M.M. and Palacios, J.M. (1988) Neurotransmitter receptors in the avian brain. I. Dopamine receptors. *Brain Research* 439, 354–359.

Dillon, J.E., Raleigh, M.J., McGuire, M.T., Bergin-Pollack, D. and Yuwiler, Y. (1992) Plasma catecholamines and social behavior in male vervet monkeys (*Cercopithecus aethiops sabaeus*). *Physiology and Behavior* 51, 973–977.

Dohms, J.E. and Metz, A. (1991) Stress-mechanisms of immunosuppression. *Veterinary Immunology and Immunopathology* 30, 89–109.

Driscoll, P., Escorihuela, R.M., Fernandez-Teruel, A., Giorgi, O., Schwegler, H., Steimer, T., Wiersma, A., Corda, M.G., Flint, J., Koolhaas, J.M., Langhans, W., Schulz, P.E., Siegel, J. and Tobena, A. (1998) Genetic selection and differential stress responses: the Roman lines/strains of rats. *Annals of the New York Academy of Sciences* 851, 501–510.

Edens, F.W. (1987) Agonistic behavior and neurochemistry in grouped Japanese quail. *Comparative Biochemistry and Physiology A, Comparative Physiology* 86, 473–479.

Etches, R., Williams, J.B. and Rzasa, J. (1984) Effects of corticosterone and dietary

changes in the hen on ovarian function, plasma LH and steroids and the response to exogenous LH-RH. *Journal of Reproduction and Fertility* 70, 121–130.

Falconer, D.S. (1981) *Introduction to Quantitative Genetics*, 2nd edn. Longman, New York.

Ferrari, F. and Giuliani, D. (1993) Behavioural effects induced in rats and chicks by D2 dopamine agonists. *Physiology and Behaviour* 54, 695–700.

Griffing, B. (1967) Selection in reference to biological groups. I. Individual and group selection applied to populations of unordered groups. *Australian Journal of Biological Science* 10, 127–139.

Griffing, B. (1976) Selection in reference to biological groups. V. Analysis of full-sib groups. *Genetics* 82, 703–722.

Gross, W.B. and Siegel, H.S. (1983) Evaluation of the heterophil/lymphocyte ratio as a measure of stress in chickens. *Avian Diseases* 27, 972–979.

Gross, W.B. and Siegel, P.B. (1988) Environment–genetic influences on immunocompetence. *Journal of Animal Science* 66, 2091–2094.

Harvey, S., Phillips, J.G., Rees, A. and Hall, T.R. (1984) Stress and adrenal function. *Journal of Experimental Zoology* 232, 633–645.

Hester, P.Y., Muir, W.M., Craig, J.V. and Albright, J. (1996a) Group selection for adaptation to multiple-hen cages: hematology and adrenal function. *Poultry Science* 75, 1295–1307.

Hester, P.Y., Muir, W.M., Craig, J.V. and Albright, J.L. (1996b) Group selection for adaptation to multiple-hen cages: production traits during heat and cold exposure. *Poultry Science* 75, 1308–1314.

Hester, P.Y., Muir, W.M. and Craig, J.V. (1996c) Group selection for adaptation to multiple-hen cages: humoral immune responses. *Poultry Science* 75, 1315–1320.

Hohenhaus, M.A., Josey, M.J., Dobson, C. and Outteridge, P.M. (1998) The eosinophil leucocyte, a phenotypic marker of resistance to nematode parasites, is associated with calm behaviour in sheep. *Immunology and Cell Biology* 76, 153–158.

Jiao, Y., Medina, L., Veenman, C.L., Toledo, C., Puelles, L. and Reiner, A. (2000) Identification of the anterior nucleus of the ansa lenticularis in birds as the homolog of the mammalian subthalamic nucleus. *Journal of Neuroscience* 20, 6998–7010.

Lang, G.F., Etches, R. and Walton, J.S. (1984) Effects of luteinizing hormone, progesterone, testosterone, estradiol and corticosterone on ovulation and luteinizing hormone release in hens treated with aminoglutethimide. *Biology of Reproduction* 30, 278–288.

Levinson, W. and Jawetz, E. (1996) *Medical Microbiology and Immunology.* Appleton and Lance, Stamford, Connecticut.

Malyshev, V.V., Vasil'eva, L.S. and Kuz'menko, V.V. (1993) The interrelationship between inflammation and the stress reaction. *Buillenten Eksperimentalnoi Biologii I Medistiny* 116, 348–349.

Maxwell, M.H. (1993) Avian blood leucocyte responses to stress. *World's Poultry Science Journal* 49, 34–43.

McCauley, D.E. and Wade, M.J. (1980) Group selection: the genotypic and demographic basis for the phenotypic differentiation of small populations of *Tribolium castaneum*. *Evolution* 34, 3–91.

Muir, W.M. (1996) Group selection for adaptation to multiple-hen cages: selection program and direct responses. *Poultry Science* 75, 447–458.

Muir, W.M. (2003a) Incorporating molecular information in breeding programs, applications and limitations. In: Muir, W.M. and Aggrey, S. (eds) *Poultry Genetics, Breeding and Biotechnology.* CAB International, Wallingford, UK, pp. 549–562.

Muir, W.M. (2003b) Indirect selection for improvement of animal well-being. In: Muir, W.M. and Aggrey, S. (eds) *Poultry Genetics, Breeding and Biotechnology*. CAB International, Wallingford, UK, pp. 247–256.

Muir, W.M. and Craig, J.V. (1998) Improving animal well-being through genetic selection. *Poultry Science* 77, 1781–1788.

Muir, W.M. and Schinckel, A. (2002) Incorporation of competitive effects in breeding programs to improve productivity and animal well being. *Proceedings 7th World Congress of Genetics Applied to Livestock Breeding* 32, 35–36.

Ozherelkov, S.V., Vargin, V.V. and Semenov, B.F. (1985) Effect of experimental information and emotional stress on the primary immune response of different strains of mice. *Zhurnal Mikrobiologii, Epidemiologii i Immunobiologii* 8, 43–46.

Popova, N.K., Kulikov, A.V., Avgustinovich, D.F., Voitenko, N.N. and Trut, L.N. (1997) Effect of domestication of the silver fox on the main enzymes of serotonin metabolism and serotonin receptors. *Genetika* 33, 370–374.

Richfield, E.K., Young, A.B. and Penney, J.B. (1987) Comparative distribution of dopamine D-1 and D-2 receptors in the basal ganglia of turtles, pigeons, rats, cats, and monkeys. *Journal of Comparative Neurology* 262, 446–463.

Siegel, P.B. and Gross, W.B. (1980) Production and persistence of antibodies in chickens to sheep erythrocytes. 1. Directional selection. *Poultry Science* 59, 1–5.

Siegel, P.B., Gross, W.B. and Cherry, J.A. (1982) Correlated responses of chickens to selection for production of antibodies to sheep erythrocytes. *Animal Blood Groups Biochemical Genetics* 13, 291–297.

Sirotkin, A.V. and Schaeffer, H.-J. (1997) Direct regulation of mammalian reproductive organs by serotonin and melatonin. *Journal of Endocrinology* 154, 1–5.

Sotowska-Brochocka, J., Martynska, L. and Licht, P. (1994) Dopaminergic inhibition of gonadotropic release in hibernating frogs, *Rana temporaria*. *General and Comparative Neurology* 93, 192–196.

Tempel, D.L. and Leibowitz, S.F. (1994) Adrenal steroid receptors: interactions with brain neuropeptide systems in relation to nutrient intake and metabolism. *Journal of Neuroendocrinology* 6, 479–501.

Wade, M.J. (1976) Group selection among laboratory populations of *Tribolium*. *Proceedings of the National Academy of Sciences USA* 73, 4604–4607.

Wade, M.J. (1977) An experimental study of group selection. *Evolution* 31, 134–153.

Wade, M.J. (1978) A critical review of the models of group selection. *Quarterly Review of Biology* 53, 101–114.

Wade, M.J. and McCauley, D.E. (1980) Group selection: the phenotypic and genotypic differentiation of small populations. *Evolution* 34, 799–812.

Wambebe, C. (1986) Influence of some dopaminoceptor agents on nitrazepam-induced sleep in the domestic fowl (*Gallus domesticus*) and rats. *Japanese Journal of Pharmacology* 40, 357–365.

Weigel, K.A., Freeman, A.E., Kehrli, M.E. Jr, Thurston, J.R. and Kelley, D.H. (1992) Relationship of *in vitro* immune function with health and production in Holstein cattle. *Journal of Dairy Science* 75, 1672–1679.

Williams, G.C. (1966) *Adaptation and Natural Selection*. Princeton University Press, Princeton, New Jersey, pp. 1–14.

Wilson, D.S. (1983) The group selection controversy and current status. *Annual Review of Ecology and Systematics* 14, 159–187.

Woolaston, R.R., Manueli, P., Eady, S.J., Barger, I.A., Le Jambre, L.F., Banks, D.J. and Windon, R. (1996) The value of circulating eosinophil count as a selection criteria for resistance of sheep to trichostrongyle parasites. *International Journal for Parasitology* 26, 123–126.

CHAPTER 14
Sensory perception: chemoreception

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ABSTRACT

The detection of environmental chemical stimulants (chemoreception) has relevance for the welfare of laying hens because they are exposed to a range of chemical environments of varying strength, duration and toxicity during their lifetime in commercial egg-production systems. Behavioural and physiological evidence that chickens have well-developed systems allowing perception of the chemical environment (via olfactory, trigeminal and gustatory systems) has been available for some time. Only recently, however, has this knowledge been applied and extended to investigate how current husbandry practices might activate or disrupt chemosensory systems. For example, there is growing evidence to suggest that chickens can detect aerial pollutants such as ammonia at concentrations routinely encountered commercially, that exposure to ammoniated environments is aversive, and that chronic pollutant exposure may affect olfactory processing. Current work is assessing the chemosensory consequences of controlled atmosphere stunning, particularly where mixtures containing carbon dioxide are used, since CO_2 causes nasal pain in humans above a threshold concentration. The potential role of olfactory and gustatory cues in the development of behavioural problems that have an adverse effect on welfare, such as feather pecking and cannibalism, also merit further study. Mounting evidence that chemosensory cues are of importance to the chicken means that we must consider the impact of the chemical environment when making welfare recommendations in modern production systems.

INTRODUCTION

The detection of environmental chemical stimulants (chemoreception) has relevance for the welfare of laying hens because they are exposed to a range of chemical environments of varying strength, duration and toxicity during their lifetime in commercial egg production systems. In the past, the importance of chemical sensitivity in the life of domestic fowl has been largely neglected, primarily as a result of historical scepticism regarding the existence of specialized chemoreception in birds in general (Jones and Roper, 1997). Over recent years however, a gradual accumulation of convincing anatomical, neurophysiological and behavioural evidence has clearly demonstrated the existence of functional chemical senses in a

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wide range of bird species, including the domestic fowl (Wenzel, 1973; Jones and Roper, 1997; Roper, 1999; Mason and Clark, 2000). The anatomical, physiological and behavioural aspects of the three main chemical senses possessed by domestic fowl (olfaction, trigeminal chemoreception and gustation) are briefly reviewed here. Later, the welfare implications of keeping hens in commercial conditions are discussed in terms of these sensory capabilities.

CHEMOSENSORY SYSTEMS

Olfaction

The olfactory system (or sense of smell) has received greater study in birds than the other specialized chemical senses (reviewed in Roper, 1999). Early unsuccessful attempts to demonstrate avian olfactory responsiveness contributed to the generally held belief that birds had little, if any, olfactory abilities. On the other hand, numerous anatomical reports demonstrated the presence of well-developed olfactory apparatus (Bang, 1971; Wenzel, 1971, 1973, 1987), indicating a functional role. Although it is no longer disputed that many avians have good olfactory abilities, these are still considered less well developed than in other vertebrate groups, especially mammals. The principal features of the olfactory system of the domestic fowl are described below.

Entrance to the nasal cavity is through paired external nares at the base of the bill, after which inspired air and odorants enter three successive chambers arranged in sequence on each side of the medial septum; the rostral concha, middle concha and caudal concha (Wenzel, 1987). In the hen the rostral concha is a simple convex flap (Bang and Wenzel, 1985) which, along with the middle concha, serves to warm and humidify incoming air. An opening to the buccal cavity in the middle concha allows inspired air to pass into the lungs for respiration and the remaining air travels to the caudal concha, the only region to contain olfactory epithelium (Wenzel, 1987). This is supported on cartilages and is ultrastructurally similar to other vertebrates, containing olfactory receptor neurones, basal cells, sustenacular cells and a mucus layer in which odorants dissolve (Wenzel, 1971). The dendrites of olfactory receptor neurones terminate at cilia in the mucus layer and their axons form the paired olfactory (1st cranial) nerves (Wenzel, 1987). Each olfactory nerve projects to an ipsilateral olfactory bulb, positioned at the anterior end of the brain. Anatomical studies reveal a strong similarity between the olfactory bulb structure of birds and other vertebrate groups, with the avian bulb following the basic vertebrate structure of concentric cell layers surrounding a ventricle (Wenzel, 1971, 1987). Five layers are present in hens: the olfactory nerve, glomerular, external plexiform, mitral cell and the granule cell layers, respectively (Hummel, 1979; McKeegan, 2002). Little is known about connections between the olfactory bulb and higher centres, but it has been recognized that the lateral olfactory tract projects to the ipsilateral piriform cortex on the lateral surface of the telencephalon (Rieke and Wenzel, 1978), with reciprocal projections to diencephalon and limbic system (Wenzel, 1987).

Among birds, there is much variation in the position, configuration and size of the olfactory bulbs in relation to the rest of the brain, as indicated in the 'relative olfactory bulb size' index (Bang and Cobb, 1968). The precise extent to which

relative olfactory bulb size relates to olfactory capabilities is not clear, but this measure has been used to rank avian species on a continuum of olfactory prowess (Bang and Cobb, 1968; Bang, 1971). Accordingly, the intermediate olfactory bulb size of the domestic fowl suggests a moderately well-developed system, just below the midpoint in a rank order of 124 avian species (Bang, 1971).

Despite good anatomical information, there has been very little detailed neurophysiological study of avian olfactory systems. Although electrical activity in the olfactory nerves of various birds was first demonstrated in the 1960s (Tucker, 1965), only recently did a study provide the first detailed physiological evidence of a well-developed avian olfactory system (McKeegan, 2002). Single olfactory bulb neurones of anaesthetized hens exhibited a range of spontaneous temporal firing patterns (McKeegan, 2002) with mean firing rates between those of mammals and reptiles (Mathews, 1972; Harrison and Scott, 1986; McKeegan, 2002). Responses to odorants (inhibition or excitation of spontaneous firing), also resembled those seen in other vertebrate groups (Kauer, 1974; Reinken and Schmidt, 1986). Further studies confirm the complexity of the system with hen olfactory bulb neurones capable of responding to small-step changes in odour concentration (McKeegan *et al.*, 2002a) and exhibiting adaptation to prolonged (2 min) odour stimulation (McKeegan and Lippens, 2003).

Numerous behavioural studies have provided compelling evidence that chickens at various stages of development can detect and respond to a wide range of olfactory stimulants in diverse contexts (reviewed in Jones and Roper, 1997). Olfaction has been implicated in the formation of attachments, the elicitation of fear responses by alarm and predator-related odours, the control of feeding and drinking and avoidance of noxious substances.

Trigeminal Chemoreception

Early indications of the importance and biological relevance of trigeminal chemoreception in birds were provided by studies of birds with bilateral olfactory nerve section (e.g. Walker *et al.*, 1979). These anosmic birds could still complete detection and discrimination tasks, albeit not at the pre-operative level of sensitivity. Such non-olfactory responses are mediated, as in other vertebrates, via the mucous membranes of the eyes, nasal cavity and mouth that are innervated by chemically sensitive free nerve endings (Silver and Finger, 1991). These arise from the trigeminal nerve (principal somatosensory nerve of the head) and form part of the 'common chemical sense', particularly associated with reflex and protective responses to irritating or painful chemical stimuli.

Anatomically, the trigeminal system of birds parallels that of mammals (Dubbledam and Karten, 1978; Kare and Mason, 1986; Silver and Finger, 1991; Mason and Clark, 2000). In the chicken, the trigeminal (5th cranial) nerve emerges from the rostrocaudal medulla and enters the trigeminal ganglion on the floor of the cranial cavity. The ganglion gives rise to various nerve branches serving the different mucosal regions of the head. The ophthalmic nerve innervates parts of the eye and the rostral part of the nasal cavity, the nasopalatine nerve (a branch of the maxilliary nerve) serves the floor and medial wall of the nasal cavity and the palate, and the mandibular branch provides sensory input to the rest of the mouth (Mason and Clark, 2000). Trigeminal free nerve endings lie in close proximity to olfactory

receptors in the nasal cavity, while trigeminal and gustatory receptors are associated in the mouth (Kare and Mason, 1986).

Although the chemoreceptive properties of the trigeminal system are well known (Tucker, 1971; Silver and Finger, 1991), the physiological characteristics of individual receptors responding to chemical stimulation have not been well characterized. In the only avian study of single afferents, McKeegan *et al.* (2002b) described the firing characteristics, thresholds and stimulus response curves of nasal receptors to noxious gaseous stimulation. These were essentially similar to those of mammals, consisting of unmyelinated C-type and A-delta polymodal nociceptors (Lucier and Egizii, 1989; Mason and Clark, 2000).

Despite clear morphological and physiological similarities, important functional differences exist between the trigeminal systems of birds and mammals. For example, birds are insensitive to capsaicin (found in chilli peppers), a potent nociceptive stimulant in mammals (Kare and Mason, 1986; Mason and Clark, 2000) but they avoid other compounds that are not irritating to mammals (Mason and Silver, 1983). These differences may affect the way that birds perceive potentially noxious chemicals in their environment.

Gustation

The role of gustation (taste) is to encourage the ingestion of food, discriminate between available foods and probably to avoid intake of noxious compounds (Kare and Mason, 1986). Generally, close contact between appropriate receptors (taste buds) and the source of chemical stimulation is required. Many studies have demonstrated an acute sense of taste in the domestic fowl.

The sensory cells that respond to different tastants are located in taste buds, which in chickens are ovoid structures consisting of a central core of sensory and sustenacular cells surrounded by follicular (sheath) cells (Berkhoudt, 1985). Reports of the number of taste buds possessed by chickens vary, probably because of differences in measurement technique, age and strain. A maximum of 250–350 taste buds have been found in adults (Berkhoudt, 1985), up to double the number found in day-old chicks. This age-related increase in sensitivity contrasts with the reduction in mammalian taste bud numbers with age. Nevertheless, the number of taste buds is small compared to mammals (e.g. humans have 9000 taste buds (Kare and Mason, 1986)), with the result that birds are attributed with poor gustatory acuity.

The chicken's taste buds are located in the palate, on the tongue and on the floor of the mouth, and they may be freely distributed in the oral mucosa or, more commonly, in close association with the salivary glands (Gentle, 1971). Their orientation in narrow rings around salivary gland openings highlights the importance of saliva in mediating taste responses (Berkhoudt, 1985). This notion is supported by reports that changes in salivary flow (as a result of zinc deficiency) affect taste-mediated behaviour (Gentle *et al.*, 1981).

The innervation of taste buds is complex, with different nerves serving different areas of the mouth. In the chicken, the lingual branch of the glossopharyngeal nerve (Berkhoudt, 1985), the palatine branch of the facial nerve (Krol and Dubbeldam, 1979) and the chorda tympani (Gentle, 1984) all carry taste (and cutaneous) information. Physiological and behavioural studies of tastants (usually presented in aqueous solution) show that chickens detect and respond to the main

taste categories: sweet, salt, sour and bitter. Unfortunately, very few studies have applied biologically relevant taste stimuli.

Naturally granivorous birds, like chickens, seem indifferent to sugars presented in food (dextrose and sucrose up to 25%; Kare and Medway, 1959) and reject strong (30%) solutions of sucrose, fructose and glucose (Gentle, 1972) and saccharin (Kare and Mason, 1986). However, modest preferences have been reported for natural sugar solutions over water (Gunther and Wagner, 1971; Gentle, 1972, 1975; Kare and Mason, 1986). Domestic fowl can taste salts and will not drink sodium chloride solutions hypertonic to their body fluids, having a low tolerance compared to species with nasal salt glands (Berkhoudt, 1985). Young chicks are even more sensitive, and will only accept NaCl solutions up to 0.9% (Pick and Kare, 1962). Domestic fowl maintained on deficient diets exhibit specific appetites for sodium or calcium to correct their intake (Hughes and Wood-Gush, 1971), which are presumably at least partly mediated by taste. These abilities are poorer in domestic fowl than in their wild ancestors, the jungle fowl (Kare and Maller, 1967). Chickens also detect sourness, produced by acid or alkaline solutions (Gentle, 1983); mineral acids are tolerated more than organic ones (Fuerst and Kare, 1962); and aversion to acid solutions can be diminished by the addition of glucose (Gentle, 1972). Many bitter compounds are unpleasant at low concentrations, and quinine hydrochloride, a commonly used standard bitter stimulus in mammals, is also rejected by chickens and provokes a strong neural response (Gentle, 1975, 1976). However, some tastants perceived as bitter by man, e.g. sucrose octacetate, are accepted by chickens, while dimethyl anthranilate, a flavouring used in human foods, is aversive and reduces food intake (Kare and Mason, 1986). Although no clear characteristic responses to neutral or palatable taste stimuli have been observed (Gentle and Harkin, 1979), aversive oral stimulants produce characteristic responses including head shaking, bill wiping and repetitive tongue and beak movements (Gentle, 1975).

Interestingly, temperature affects chickens' ingestive behaviour. They readily accept cold water, but liquids above ambient temperature cause hesitance and those above body temperature are rejected (Gentle, 1979; Kare and Mason, 1986). It should be borne in mind that birds' selection of food may be strongly influenced by temperature, visual properties and surface texture (Mason and Reidinger, 1983; Kare and Mason, 1986). Furthermore, individual variations in taste preferences and test context can also affect the observed response (Kare and Mason, 1986; Mason and Clark, 2000). Clearly chickens can taste, but they may not perceive similar sensations to humans, as illustrated by the dissimilar responses to sweet and bitter compounds. The presence and position of the choana, a large opening in the palate leading directly to the nasal cavity, implies a possible role for retrograde olfaction in the avian taste experience (Berkhoudt, 1985; Mason and Clark, 2000).

WELFARE IMPLICATIONS

Clearly, the laying hen possesses sensory systems that detect and distinguish chemical cues in its environment. It seems reasonable to assume that factors that activate or disrupt these systems (particularly over long periods) might impact on welfare. Studies related to welfare have concentrated on two issues, aerial

pollution in poultry houses (mainly ammonia exposure) and gas (controlled atmosphere) stunning. These are reviewed below. The possible role of olfaction and/or gustation in the development of feather pecking is also briefly discussed. Studies of the role of 'olfactory therapy' in environmental enrichment are more fully described elsewhere (Jones and Roper, 1997; R.B. Jones, 2002, see also Chapter 20 in this volume).

Aerial Pollution in Poultry Housing

Poor air quality in poultry housing can be generally attributed to an emphasis on ventilation systems which control the thermal environment but fail to prevent accumulation of aerial pollution consisting of particulate, gaseous and biologically active components (Wathes *et al*., 1983, 1997). Pollutants are the products of animal respiration, microbiological decomposition of manure and airborne dust from litter, food and the animals (Harry, 1978, Wathes *et al*., 1983). Gaseous aerial pollutants are diverse and include carbon dioxide, methane, nitrous oxide, hydrogen sulphide and ammonia (Wathes *et al*., 1991; Wathes, 1998). Of these, ammonia is the most abundant and, arguably, the most harmful. A potent water-soluble irritant, airborne ammonia is rapidly absorbed in the upper airways; at higher concentrations it can also adversely affect the lower respiratory system. Dermal and ocular irritation, decreased food intake, reduced growth and increased propensity to respiratory disease have all been associated with keeping poultry in highly ammoniated environments (Kristensen and Wathes, 2000).

The amount of ammonia experienced by laying hens may depend on several factors such as the housing system, management, and, to a certain extent, the point in the production cycle (Groot Koerkamp *et al*., 1998). Typical ammonia measurements vary, but in cage systems have been reported in the range 9–4 parts per million (ppm) (Maghirang *et al*., 1991) and 33–53 ppm (McQuitty *et al*., 1985). Generally, somewhat higher average concentrations are found in broiler houses (mean 27.1 ppm, max 56.3 ppm) than layer accommodation (mean 11.9, max 67.1 ppm, cage system; mean 8.3, max 63.9 ppm, perchery/deep litter), although these figures show that laying hens may have to endure higher maximum levels, presumably short-term exposures (Groot Koerkamp *et al*., 1998).

Current guidelines and limits for aerial pollutants such as ammonia are designed to help control environmental emissions and protect poultry workers and there are no specific livestock recommendations. Recommended human occupational exposure limits for ammonia are 25 ppm for up to 8 h and 35 ppm for short-term exposures up to 15 min (Health and Safety Executive, 2002). In addition to welfare insults such as respiratory disease or severe keratoconjunctivitis (Kristensen and Wathes, 2000), the general implications of keeping poultry in heavily polluted environments are a growing concern. Before these can be assessed, it must be determined whether pollutants can be detected by chickens and, crucially, if acute or chronic exposure to them is aversive or even painful. These questions are particularly pertinent for laying hens that, compared to broilers or even finishing pigs, have a relatively long production life.

There is good evidence that both broilers and layers can detect, and avoid, ammoniated environments. When given free choice between identical chambers nominally containing 0, 25 or 45 ppm ammonia, adult laying hens displayed a

relative preference for the fresh air compartment but they did not differentiate between the 25 and 45 ppm atmospheres and aversion to the polluted compartments was not immediate (Kristensen *et al*., 2000). Using broilers, Jones (2002) showed that mean visit duration in a series of chambers containing different ammoniated environments was directly related to ammonia concentration (0 ppm, 37 min; 10 ppm, 28 min; 20 ppm, 20 min; 40 ppm, 15 min). These delayed preferences suggest that ammonia concentrations as low as 10 ppm are perceived (and avoided), but the fact that birds spent any time at all in polluted compartments throws doubt on the role of immediate chemosensory perception and protective reflexes in mediating these responses. Although occupancy of all the available aerial environments may be related to exploratory tendencies and the costs of moving between compartments, delayed aversion may result from feelings of 'malaise', perhaps as a result of alterations to blood acid–base balance (Kristensen *et al*., 2000; Jones, 2002). McKeegan *et al*. (2004) examined the overt behavioural responses of hens to acute (7 s) pulses of ammonia at (5, 10, 20, 40 and 100 ppm), and found evidence of chemoreception (e.g. interruption of ongoing behaviour, mandibulation) at 5 ppm, and avoidance reactions (e.g. struggling, eye shutting) at 20 ppm and above. In the light of these findings (and the electrophysiological results detailed below), it seems unlikely that the ammoniated compartments in the above choice chamber experiments were not instantly perceived. Whatever the mechanism, these findings provide clear evidence of aversion to ammonia at relatively low levels (by commercial standards). Further, the report that chickens moved through an increasingly weighted door to leave an ammoniated (40 ppm) environment and that aversion responses were unaffected by previous experience of ammonia adds weight to the welfare argument (Jones, 2002).

While behavioural studies are very useful in determining birds' preferences, they do not identify the sensory systems mediating perception and avoidance. Odorous, irritant gases such as ammonia have the potential to be olfactory, trigeminal or combining stimulants (or may even be perceived as a tastant, particularly at high concentrations). Recent electrophysiological studies allowed us, for the first time, to begin identifying the precise physiological systems involved in hens' responses to biologically (and commercially) relevant gases. For example, McKeegan *et al*. (2002a) determined hens' olfactory responses by recording the activity of single olfactory bulb neurones to a range of ammonia concentrations. Response thresholds ranged from 2.5 to 60 ppm, with a median of 3.75 ppm, well within ammonia concentrations reported commercially. Variations in response magnitude of single neurones with even small step changes in ammonia concentration were also observed, illustrating the sensitivity of the system. In an attempt to mimic the chronic exposure experienced by hens in polluted housing systems, the experiment was repeated using birds that had been continuously exposed to 20 ppm ammonia for 12 days. While overall response types and magnitudes were similar to those seen in 'naive' birds, the median olfactory bulb neurone response threshold increased from 3.75 to 10 ppm (D.E.F. McKeegan *et al*., unpublished). Although the mechanism behind this increase can only be speculated upon, such changes show that prolonged ammonia exposure alters olfactory processing and could affect welfare.

Nasal trigeminal thresholds have been determined by recording the responses of single polymodal nociceptors from the ethmoidal nerve to acute ammonia

exposure. Nociceptors preferentially respond to noxious (potentially tissue-damaging) stimuli. These receptors exhibited a range of thresholds (from 190 to 6250 ppm, mean 2320 ppm), and the clear concentration-related responses indicated that information about both the presence and the amount of ammonia in the environment is transmitted (McKeegan *et al.*, 2002b). However, the thresholds recorded here suggest that ammonia pollution in poultry houses is unlikely to cause nasal pain. Ongoing studies suggests that trigeminal nociceptive thresholds for ammonia in the buccal cavity are considerably higher than nasal thresholds (D.E.F. McKeegan and M.J. Gentle, unpublished). The ocular mucosa, however, may have a lower nociceptive threshold than the nose (Comettomuniz and Cain, 1995), and eye irritation and pain resulting from pollutant exposure cannot be ruled out.

Although the trigeminal system is the source of irritation responses, it is not clear whether irritation is caused by low-level activation of nociceptors or whether a separate group of receptors is involved. Although 'irritation receptors' have never been described in any species, available nociceptive thresholds in various studies seem high compared to the levels of irritants known from psychophysical studies to cause discomfort to humans. A few neurones responding to ammonia in the range 5–100 ppm have been recorded from the ethmoidal nerve of the hen (D.E.F. McKeegan *et al.*, unpublished), and these merit further investigation as a potential source of irritation responses.

Collectively, available behavioural and electrophysiological findings strongly suggest that keeping laying hens in environments polluted with ammonia is likely to harm their welfare. Ammoniated environments appear to be aversive, and prolonged supra-threshold pollutant exposure may be associated with loss of olfactory ability, either by damage to the olfactory epithelium, by an increase in mucus secretion, or simply as a result of ammonia preferentially occupying olfactory receptors and masking other odours. These effects could disrupt essential behaviours such as food location, the identification of familiar environments, and even social interactions. In the absence of specific recommendations for poultry, the only current route for improvement is to reduce human occupational exposure limits and thereby effectively reduce livestock pollutant exposure. Even to protect human health, there is evidence that current exposure limits are too high and should be revised downwards, with levels of 10 ppm ammonia and lower (Jones, 2002; Wathes *et al.*, 2003) considered desirable to promote poultry (and poultry worker) welfare.

Controlled Atmosphere Stunning

Controlled atmosphere (gas) stunning is an attractive prospect for improving the welfare of poultry at slaughter, as it avoids the need for live shackling, a stressful and painful procedure (Gentle and Tilston, 2000). Instead, the birds are conveyed directly from their transport crates into the gas environment and are then shackled when unconscious. Gas stunning also eliminates the possibility that some birds will not be stunned adequately before bleed-out as well as the negative effects of electrical stunning on carcass quality, e.g. muscle haemorrhages and broken bones (Hoen and Lankhaar, 1999).

The gas stunning methodologies available can be summarized as follows: anoxia – the replacement of oxygen by argon or nitrogen; hypercapnic anoxia –

application of mixtures of argon and carbon dioxide (CO_2); hypercapnic hypoxia – use of high levels of CO_2 (>80%); and hypercapnic hyperoxygenation – a combination of high levels of oxygen and CO_2 (e.g. 40% CO_2 and 30% oxygen) (Raj and Tserveni-Gousi, 2000, Barton Gade *et al.*, 2001). Some 'multiphase' systems use combinations of these approaches, such as hypercapnic hyperoxygenation to induce unconsciousness in an anaesthetic phase, followed by hypercapnic hypoxia to prevent consciousness being regained (Barton Gade *et al.*, 2001). In the UK, most attention has been given to anoxia-based systems, whereas multiphase systems have received more interest in continental Europe. Generally, these systems have been developed for broiler processing but they could also be applied to the slaughter of spent hens.

While these systems offer several welfare and meat quality benefits, the extent to which conscious birds are exposed to potentially aversive gaseous environments in these systems remains unclear. This uncertainty has contributed to legislative inertia and means that while gas stunning is not forbidden, it is yet to be specifically approved in many European countries. Knowledge of chemoreceptive responses in poultry is essential to ensure that one potentially painful and distressing slaughter method is not replaced with another.

Unlike exposure to pollutants such as ammonia, any negative chemosensory sensations induced by gas stunning are likely to be transient, and in any case before the bird loses consciousness. Behavioural responses to gas stunning mixtures include gasping, headshaking, loss of posture (sometimes associated with attempts to regain balance) and convulsions; their incidence varies between individuals and the type of gases applied (Poole and Fletcher, 1995; Lambooij *et al.*, 1999; Gerritzen *et al.*, 2000; Webster and Fletcher, 2001). For example, anoxic mixtures have been associated with increased wing flapping and convulsions (Lambooij *et al.*, 1999), while there is evidence that oxygen supplementation during hypercapnia minimizes signs of agitation and asphyxia (Coenen *et al.*, 2000). It is difficult to define perception and to identify the precise sensory systems involved from measurement of the above behavioural responses. Another complicating factor is that reflexes such as gasping and respiratory distress indicate the involvement of lower airway receptors, in addition to the potential activation of olfactory, trigeminal and gustatory receptors.

The use of CO_2 in gas stunning mixtures continues to be debated, since exposure to this gas above certain levels is known to be painful in humans (Kobal, 1985). Although CO_2 is not an irritant, it is a commonly used nasal nociceptive stimulus eliciting painful sensations in humans at thresholds of between 40% and 55% (Anton *et al.*, 1992). The thresholds of hen nasal and buccal trigeminal nociceptors to CO_2 are currently being investigated (McKeegan *et al.*, 2002b; D.E.F. McKeegan and M.J. Gentle, unpublished). Preliminary results suggest buccal thresholds of 40–50%, similar to human experiences.

To eliminate the confounding factors of respiratory distress and eventual loss of consciousness, a recent behavioural study examined hens' responses to acute (7 s) CO_2 exposure. Evidence of detection (interruption of behaviour, mandibulation) was seen at low levels (10%), with gasping and headshaking appearing at higher levels. Unlike their responses to ammonia, the hens seemed less able to orient to the source of CO_2, and did not avoid even high concentrations (80%). Like all gases used for controlled atmosphere stunning, CO_2 is odourless and a lack of olfactory sensitivity to CO_2 and argon has been confirmed electrophysiologically

(no response in olfactory bulb neurones; D.E.F. McKeegan *et al.*, unpublished). It would seem that acute CO_2 exposure activates only the trigeminal (and possibly gustatory) system, and that accurate orientation and avoidance depends on olfactory cues (McKeegan *et al.*, 2004).

While available information is incomplete, it would appear that gaseous environments, especially those containing high levels of CO_2 (>40%), might reduce welfare in the initial part of the gas stunning procedure. A full welfare assessment of controlled atmosphere stunning cannot be made until pain and aversion thresholds to a range of gas mixtures are defined. This work is under way.

Feather Pecking and Cannibalism

Feather pecking and cannibalism in laying hens remains a serious welfare and economic problem in the egg industry, which is likely to be exacerbated by the planned EU phase-out of traditional battery cages, since pecking problems tend to be more difficult to control in alternative systems. Outbreaks of this damaging behaviour are unpredictable and despite a large number of studies its complex, multifactorial causation is still not fully understood.

Savory and Mann (1997) first suggested that ingestion of feathers pulled from other birds or moulted loose feathers from the floor might be related to the development of damaging pecking. Feather eating is common in pen-housed pullets during the growing period and this behaviour was positively correlated with the extent of feather pecking and cannibalism after the onset of lay (McKeegan, 1999; McKeegan and Savory, 1999). In an attempt to ascertain what makes the feathers of other birds attractive as a substrate for pecking, and what encourages feather ingestion (eaten feathers are not digested and have no nutritive value), McKeegan and Savory (2001) asked if the presence of odoriferous preen (uropygial) oil on the surface of the feathers was influential. In support of this idea, feathers around the preen gland seem to be particularly targeted when pecking first takes place (Savory and Mann, 1997, 1999). When hens were offered loose conspecific feathers that were either untreated or washed (to remove preen oil), individuals both with and without a previous history of feather pecking ate more unwashed feathers (McKeegan and Savory, 2001). Thus, preen oil on feathers may provide attractive olfactory and/or gustatory cues. Recently, Sandilands *et al.* (2004) found differences in the fatty acid composition of preen oil from pecked and non-pecked hens. It is conceivable that such differences might explain the common observation that some birds are targeted for pecking while others remain unharmed (Savory, 1995). Further studies are necessary to determine what aspects of preen oil, if any, contribute to the attractiveness of conspecific feathers, and whether this information can be used to improve our understanding of how feather pecking develops.

CONCLUSIONS

Behavioural and physiological evidence that chickens have well-developed systems allowing perception of the chemical environment (particularly via olfactory and gustatory cues) has been available for some time. Only recently, however, has this knowledge been applied and extended to investigate how current husbandry

practices might activate or disrupt chemosensory systems. The examples described here illustrate that all the chemical senses can respond to stimuli experienced in routine commercial contexts. Mounting evidence that chemosensory cues are of importance to the chicken means that we must consider the impact of the chemical environment when making welfare recommendations in modern production systems.

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REFERENCES

Anton, F., Euchner, I. and Handwerker, H.O. (1992) Psychophysical examination of pain induced by defined CO_2 pulses applied to the nasal-mucosa. *Pain* 49, 53–60.

Bang, B.G. (1971) Functional anatomy of the olfactory system in 23 orders of birds. *Acta Anatomica* 79, 1–79.

Bang, B.G. and Cobb, S. (1968) The size of the olfactory bulb in 108 species of birds. *Auk* 85, 55–61.

Bang, B.G. and Wenzel, B.M. (1985) Nasal cavity and olfactory system. In: King, A.S. and McClelland, J. (eds) *Form and Function in Birds,* Vol. 3. Academic Press, New York, pp. 195–225.

Barton Gade, P., von Holleben, K. and von Wenzlawowicz, M. (2001) Animal welfare and controlled atmosphere stunning (CAS) of poultry using mixtures of carbon dioxide and oxygen. *World's Poultry Science Journal* 57, 189–200.

Berkhoudt, H. (1985) Structure and function of avian taste receptors. In: King, A.S. and McClelland, J. (eds) *Form and Function in Birds,* Vol. 3. Academic Press, New York, pp. 463–496.

Coenen, A., Smit, A., Zhongua, L. and Luijtelaar, G. (2000) Gas mixtures for anaesthesia and euthanasia in broiler chickens. *World's Poultry Science Journal* 56, 225–234.

Comettomuniz, J.E. and Cain, W.S. (1995) Relative sensitivity of the ocular trigeminal, nasal trigeminal and olfactory systems to airborne chemicals. *Chemical Senses* 20, 191–198.

Dubbeldam, J.L. and Karten, H.J. (1978) The trigeminal system in the pigeon (*Columba livia*). I. Projections of the Gasserian ganglion. *Journal of Comparative Neurology* 180, 661.

Fuerst, F.F. and Kare, M.R. (1962) The influence of pH on fluid tolerances and preferences. *Poultry Science* 41, 167–171.

Gentle, M.J. (1971) The lingual taste buds of *Gallus domesticus* L. *British Poultry Science* 12, 245–248.

Gentle, M.J. (1972) Taste preference in the chicken, *Gallus domesticus* L. *British Poultry Science* 13, 141–155.

Gentle, M.J. (1975) Gustatory behaviour of the chicken and other birds. In: Wright, P., Caryle, P.G. and Vowles, D.M. (eds) *Neural and Endocrine Aspects of Behaviour in Birds*. Elsevier, Amsterdam, pp. 305–318.

Gentle, M.J. (1976) Quinine hydrochloride acceptability after water deprivation in *Gallus domesticus*. *Chemical Senses and Flavour* 2, 121–128.
Gentle, M.J. (1979) Effects of water temperature on short-term water intake and medullary neuronal responses in the hen. *British Poultry Science* 20, 533–539.
Gentle, M.J. (1983) The chorda tympani nerve and taste in the chicken. *Experentia* 39, 1002–1003.
Gentle, M.J. (1984) Sensory functions of the chorda tympani nerve in the chicken. *Experentia* 40, 1253–1255.
Gentle, M.J. and Harkin, C. (1979) The effect of sweet stimuli on oral behaviour in the chicken. *Chemical Senses and Flavour* 4, 183–190.
Gentle, M.J. and Tilston, V.L. (2000) Nociceptors in the legs of poultry: implications for potential pain in pre-slaughter shackling. *Animal Welfare* 9, 227–236.
Gentle, M.J., Dewar, W.A. and Wight, P.A.L. (1981) The effects of zinc deficiency on oral behaviour and taste bud morphology in chicks. *British Poultry Science* 22, 263–273.
Gerritzen, M.A., Lambooij, E., Hillebrand, S.J.W., Lankhaar, J. and Pieterse, C. (2000) Behavioural responses of broilers to different gaseous atmospheres. *Poultry Science* 79, 928–933.
Groot Koerkamp, P.W.G., Metz, J.H.M., Uenk, G.H., Phillips, V.R., Holden, M.R., Sneath, R.W., Short, J.L., White, R.P., Hartung, J., Seedorf, J., Schroder, M., Linkert, K.H., Pedersen, S., Takai, H., Johnsen, J.O. and Wathes, C.M. (1998) Concentrations and emissions of ammonia in livestock buildings in Northern Europe. *Journal of Agricultural Engineering Research* 70, 79–95.
Gunther, W.C. and Wagner, M.W. (1971) Preferences for natural and artificial sweeteners in heat stressed chicks of different ages. *Proceedings of the Indian Academy of Sciences* 81, 401–409.
Harrison, T.A. and Scott, J.W. (1986) Olfactory bulb responses to odor stimulation: analysis of response pattern and intensity relationships. *Journal of Neurophysiology* 56, 1571–1589.
Harry, E.G. (1978) Air pollution in farm buildings and methods of control: a review. *Avian Pathology* 7, 441–454.
Health and Safety Executive (2002) *Occupational Exposure Limits. EH40/2002.* Health and Safety Executive, London.
Hoen, T. and Lankhaar, J. (1999) Controlled atmosphere stunning of poultry. *Poultry Science* 78, 287–289.
Hughes, B.O. and Wood-Gush, D.G.M. (1971) A specific appetite for calcium in domestic chickens. *Animal Behaviour* 19, 490–499.
Hummel, G. (1979) The fine structure of the bulbus olfactorius in the hen. *Zentralblatt für Veterinarmedizin C: Anatomie, Histologie, Embryologie* 8, 289–306.
Jones, E.K.M. (2002) Behavioural responses of broiler fowl to atmospheric ammonia. PhD thesis, University of Bristol, UK.
Jones, R.B. (2002) The role of comparative psychology in the development of effective environmental enrichment strategies to improve poultry welfare. *International Journal of Comparative Psychology* 15, 1–29.
Jones, R.B. and Roper, T.J. (1997) Olfaction in the domestic fowl: a critical review. *Physiology and Behavior* 62, 1009–1018.
Kare, M.R. and Maller, O. (1967) Taste and food intake in domesticated and Jungle fowl. *Journal of Nutrition* 92, 191.
Kare, M.R. and Mason, J.R. (1986) The chemical senses in birds. In: Sturkie, P.D. (ed.) *Avian Physiology*, 4th edn. Springer, New York, pp. 59–73.
Kare, M.R. and Medway, W. (1959) Discrimination between carbohydrates by the fowl. *Poultry Science* 38, 1119.

Kauer, J.S. (1974) Response patterns of amphibian olfactory bulb neurones to odour stimulation. *Journal of Physiology* 243, 695–715.

Kobal, G. (1985) Pain-related electrical potentials of the human nasal mucosa elicited by chemical stimulation. *Pain* 22, 151–163.

Kristensen, H.H. and Wathes, C.M. (2000) Ammonia and poultry welfare: a review. *World's Poultry Science Journal* 56, 235–245.

Kristensen, H.H., Burgess, L.R., Demmers, T.G.H. and Wathes, C.M. (2000) The preferences of laying hens for different concentrations of atmospheric ammonia. *Applied Animal Behaviour Science* 68, 307–318.

Krol, C.P.M. and Dubbeldam, J.L. (1979) On the innervation of tastebuds by n. facialis in the mallard, *Anas platyrhnchos* L. *Netherlands Journal of Zoology* 29, 267–274.

Lambooij, E., Gerritzen, M.A., Engel, B., Hillebrand, S.J.W., Lankhaar, J. and Pieterse, C. (1999) Behavioural responses during exposure of broiler chickens to different gas mixtures. *Applied Animal Behaviour Science* 62, 255–265.

Lucier, G.E. and Egizii, R. (1989) Characterization of cat nasal afferents and brain stem neurones receiving ethmoidal input. *Experimental Neurology* 103, 83–89.

Maghirang, R.G., Manbeck, H.B., Roush, W.B. and Muir, F.V. (1991) Air contaminant distributions in a commercial laying house. *Transactions of the ASAE* 34, 2171–2180.

Mason, J.R. and Clark, L. (2000) The chemical senses in birds. In: Whittow, G.C. (ed.) *Sturkie's Avian Physiology,* 5th edn. Academic Press, London, pp. 39–56.

Mason, J.R. and Reidinger, R.F. (1983) Importance of color for methiocarb-induced taste aversion in red-winged blackbirds. *Journal of Wildlife Management* 47, 383–393.

Mason, J.R. and Silver, W.L. (1983) Trigeminally mediated odor aversions in starlings. *Brain Research* 269, 196–199.

Mathews, D.F. (1972) Response patterns of single neurons in the tortoise olfactory epithelium and olfactory bulb. *Journal of General Physiology* 60, 166–180.

McKeegan, D.E.F. (1999) An investigation of factors underlying the development of feather pecking and cannibalism in commercial layer pullets. PhD thesis, The University of Edinburgh, UK.

McKeegan, D.E.F. (2002) Spontaneous and odour evoked activity in single avian olfactory bulb neurones. *Brain Research* 929, 48–58.

McKeegan, D.E.F. and Lippens, N. (2003) Adaptation responses of single avian olfactory bulb neurones. *Neuroscience Letters* 344 (2), 83–86.

McKeegan, D.E.F. and Savory, C.J. (1999) Feather eating in layer pullets and its possible role in the aetiology of feather pecking damage. *Applied Animal Behaviour Science* 65, 73–85.

McKeegan, D.E.F. and Savory, C.J. (2001) Feather eating in individually caged hens which differ in their propensity to feather peck. *Applied Animal Behaviour Science* 73, 131–140.

McKeegan, D.E.F., Demmers, T.G.M., Wathes, C.M., Jones, R.B. and Gentle, M.J. (2002a) Stimulus-response functions of single avian olfactory bulb neurones. *Brain Research* 953, 101–111.

McKeegan, D.E.F., Demmers, T.G.H., Wathes, C.M., Jones, R.B. and Gentle, M.J. (2002b) Response characteristics of nasal trigeminal nociceptors in *Gallus domesticus*. *Neuroreport* 13, 1033–1035.

McQuitty, J.B., Feddes, J.J.R. and Leonard, J.J. (1985) Air-quality in commercial laying barns. *Canadian Agricultural Engineering* 27, 13–19.

Pick, H. and Kare, M.R. (1962) The effect of artificial cues of the measurement of taste preference in the chicken. *Journal of Comparative and Physiological Psychology* 55, 342–345.

Poole, G.H. and Fletcher, D.L. (1995) A comparison of argon, carbon dioxide and nitrogen in a broiler killing system. *Poultry Science* 74, 1218–1223.

Raj, M. and Tserveni-Gousi, A. (2000) Stunning methods for poultry. *World's Poultry Science Journal* 56, 291–304.

Reinken, U. and Schmidt, U. (1986) Reactions of olfactory bulb neurons to different stimulus intensities in laboratory mice. *Experimental Brain Research* 63, 151–157.

Rieke, G.K. and Wenzel, B.M. (1978) Forebrain projections of the pigeon olfactory bulb. *Journal of Morphology* 158, 41–56.

Roper, T.J. (1999) Olfaction in birds. *Advances in the Study of Behaviour* 28, 247–332.

Sandilands, V., Powell, K., Keeling, L. and Savory, C.J. (2004) Preen gland function in layer fowls. 2. Factors affecting preen oil fatty acid composition. *British Poultry Science*, 45.

Savory, C.J. (1995) Feather pecking and cannibalism. *Worlds Poultry Science Journal* 51, 215–219.

Savory, C.J. and Mann, J.S. (1997) Behavioural development in groups of pen-housed pullets in relation to genetic strain, age and food form. *British Poultry Science* 38, 38–47.

Savory, C.J. and Mann, J.S. (1999) Feather pecking in groups of growing bantams in relation to floor litter substrate and plumage colour. *British Poultry Science* 40, 565–572.

Silver, W.L. and Finger, T.E. (1991) The trigeminal system. In: Getchell, T.V. (ed.) *Smell and Taste in Health and Disease*. Raven Press, New York, pp. 97–107.

Tucker, D. (1965) Electrophysiological evidence for olfactory function in birds. *Nature* 207, 34–36.

Tucker, D. (1971) Nonolfactory responses from the nasal cavity: Jacobson's organ and the trigeminal system. In: Beidler, L.M. (ed.) *Chemical Senses 1: Olfaction*. Springer, Berlin, pp. 151–181.

Walker, J.C., Tucker, D. and Smith, J.C. (1979) Odor sensitivity mediated by the trigeminal nerve in the pigeon. *Chemical Senses and Flavour* 4, 107–116.

Wathes, C.M. (1998) Aerial emissions from poultry production. *World's Poultry Science Journal* 54, 241–251.

Wathes, C.M., Jones, C.D.R. and Webster, A.J.F. (1983) Ventilation, air hygiene and animal health. *Veterinary Record* 113, 554–559.

Wathes, C.M., Johnson, H. and Carpenter, G.A. (1991) Air hygiene in a pullet house: effects of air filtration on aerial pollutants measured *in vivo* and *in vitro*. *British Poultry Science* 32, 31–46.

Wathes, C.M., Holden, M.R., Sneath, R.W., White, R.P. and Phillips, V.R. (1997) Concentrations and emission rates of aerial ammonia, nitrous oxide, methane, carbon dioxide, dust and endotoxin in UK broiler and layer houses. *British Poultry Science* 38, 14–28.

Wathes, C.M., Demmers, T.G.M. and Xin, H. (2003) Ammonia concentrations and emissions in livestock production facilities: guidelines and limits in the USA and UK. In: *Proceedings of the 2003 ASAE Annual International Meeting*, Las Vegas, USA, Paper No. 034112.

Webster, A.B. and Fletcher, D.L. (2001) Reactions of laying hens and broilers to different gases used for stunning poultry. *Poultry Science* 80, 1371–1377.

Wenzel, B.M. (1971) Olfaction in birds. In: Beidler, L.M. (ed.) *Chemical Senses 1: Olfaction*. Springer, Berlin, pp. 432–448.
Wenzel, B.M. (1973) Chemoreception. In: Farner, D.S. and King, J.R. (ed.) *Avian Biology,* Vol. 3. Academic Press, New York, pp. 389–415.
Wenzel, B.M. (1987) The olfactory and related systems in birds. *Annals of the New York Academy of Sciences* 519, 167–149.

CHAPTER 15
Vision in the laying hen

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ABSTRACT

It is important to consider the hen's vision when judging how dim artificial lighting may affect her welfare. Inappropriate lighting might constrain the quantity or quality of visual information available to the bird or adversely affect the functional development of vision. It seems reasonable to suggest that lighting in poultry houses should allow the development of normal vision and allow hens to see well enough to carry out critical visual tasks. Understanding vision will highlight variances between the hen's visual abilities and the light environment provided. Various visual abilities are important. The colour (spectral) sensitivity of the hen is known and this has implications: first, for how brightness is measured in units relevant to a hen; second, how hens perceive notionally (to humans) white light; and third, implies that the provision of ultraviolet light in poultry houses may be beneficial. Some have argued that the 100 Hz flicker from fluorescent lights might affect poultry welfare in a similar manner to the effects that visible flicker have on humans, but in fact it is known that hens do not perceive the flicker from fluorescent lights. Ocular accommodation, buphthalmus or other abnormalities may be affected by the brightness and photoperiod of the rearing light environment, although the extent of these in laying hens housed under commercial lighting regimes is unclear. The effect of the light environment on spatial acuity is unknown, although it will determine the level of structural information that can be extracted from a visual scene. Whether or not hens possess any sensitivity to polarized light is also unknown, although its existence in other bird species is contentious. Artificial light is not polarized, but if hens have some sensitivity to it, its inclusion in poultry houses may have some benefits. Recent work indicates that pupil size fluctuations may indicate the salience of images to a hen and could provide a novel means for behavioural and welfare research. While knowledge of vision in the laying hen is deep in places, other areas need further exploration to understand fully the consequences, if any, of currently operated, commercial light environments.

INTRODUCTION

This chapter considers pertinent features of the avian visual system that may have relevance to welfare. The interaction between lighting, vision and welfare has been

reviewed recently by Prescott *et al*. (2003). A review of the structure of the chicken's eye can be found in King-Smith (1971).

THE HEN'S EYE, VISUAL FIELDS AND VISUAL ASYMMETRY

The chicken's field of view is approximately 300° with only a 30° overlap in which binocular vision could occur; this is characteristic of prey rather than predator animals. A hen's eye is relatively immobile in its socket, so large changes in view are attained by swift head movements aided by a long, flexible neck and lightweight head. Monocular (lateral) and binocular (frontal) vision project to the brain along the retino-thalamic and retino-tectal pathways, respectively (Günturkün, 1993). Since there is little cross-over of the retino-thalamic pathways from each eye, and since the brain's hemispheres are relatively poorly connected, monocular images from the right eye arrive and are processed in the left hemisphere and vice versa. Binocular vision, via the tectofugal pathway, probably involves both hemispheres utilizing specific 'cross-over' projections.

Hens also exhibit specialized lateralization of visual function. The left eye (right brain hemisphere) is preferentially involved in the analysis of novelty and spatial configuration of the environment (Rashid and Andrew, 1989; Vallortigara and Andrew, 1991), which is more noticeable in males than females (e.g. Workman and Andrew, 1989). The right eye (left hemisphere) appears to be involved in conspecific recognition (Andrew and Dharmaretnam, 1993).

The hen's eyes are comparatively large and of similar weight to the brain. The visible portion belies their actual size and shape; an adult hen's eye is approximately 17 mm wide, 14 mm deep and is surprisingly 'flattened'. This flattening may allow an image to be focused across a wider area of the retina than for 'rounder' eyes (King-Smith, 1971) or may simply be a space- and weight-saving adaptation (Martin, 1993). However, a flattened shape has the potential problem of creating a small, albeit bright, image and as light levels dim, Martin (1982) argued that pooling of signals (summation) from individual photoreceptors becomes less effective than for larger eyes. This is because the image is projected over a greater number of receptors in larger eyes and summation becomes more effective as the number of available photoreceptors increases. One consequence may be that although the human eye works over an astonishing 11 orders of magnitude, the dimmest orders may be unavailable to hens.

VISUAL FUNCTION

Spectral Sensitivity

Hens have a number of adaptations to their colour perception apparatus that are not shared by humans. First, they have three types of photoreceptor compared with just rods and cones in humans (King-Smith, 1971). The additional photoreceptor is a double cone; its function is unclear though it does respond to incident light. Second, hens have four photoreactive pigments associated with cone cells, which are responsible for photopic colour vision (Yoshizawa, 1992), compared with three in humans; these are maximally sensitive at wavelengths of 415, 455,

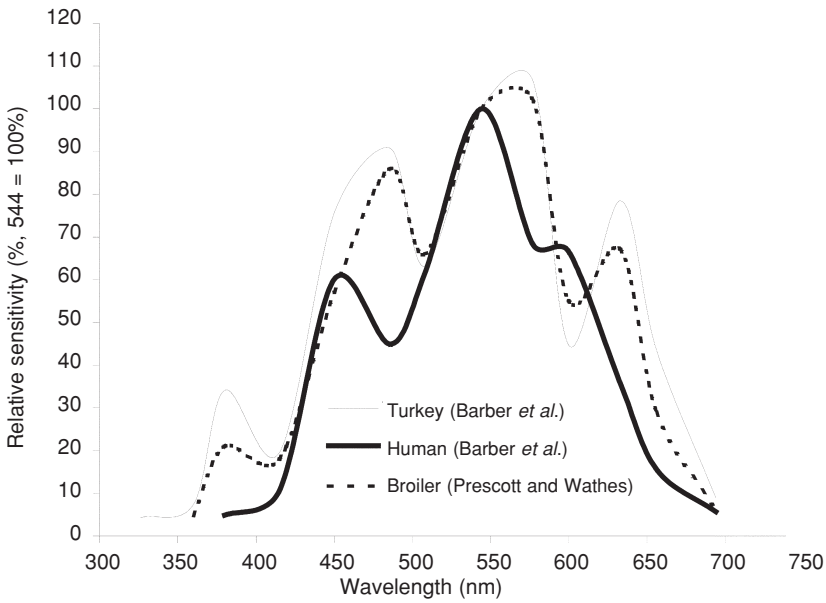

Fig. 15.1. Spectral sensitivity of humans, chickens and turkeys (from Prescott and Wathes, 1999; C. Barber, unpublished data).

508 and 571 nm versus 419, 531 and 558 nm in humans (Dartnall *et al.,* 1983). Third, coloured oil droplets in the tips of the hen's cone cells filter incident light before it reaches the photoreactive pigments, and these are associated variously with individual cone cell species (Bowmaker and Knowles, 1977). The spectral sensitivity curve derived for chickens by Prescott and Wathes (1999) using a behavioural test differs from that of the human: the relative response is broader and ultraviolet A radiation (UV_A; $320 < \lambda < 400$ nm) can be perceived (Fig. 15.1). The overall effect of these anatomical differences is a visual system that is well adapted to collecting spectral information. However, the penalty may be that a high illuminance is required for the system to work to its full potential.

The implications of the chicken's spectral sensitivity are threefold. First, the unit with which we have traditionally measured illuminance in poultry houses, the lux, is inaccurate because it will not correlate well with the perceived brightness of different light sources, since it uses human spectral sensitivity. Using the traditional view that brightness perception is based upon the sum of the individual cone responses, we calculate that for typical fluorescent and incandescent luminaires illuminated to the same lux level – and consequently iso-luminant for humans – chickens would perceive the incandescent bulb as ~20% brighter than the fluorescent tube. Alternative units for measuring chicken-perceived illuminance, the 'clux' or 'galluminance', were derived by Prescott and Wathes (1999) and Nuboer *et al.* (1992a), respectively. However, it is also conceivable that the double cone has a more prominent role in luminance perception (Osorio *et al.*, 1999). Second, the range of available wavelengths emitted from luminaires may constrain the flow of colour-mediated information, e.g. if social information is imparted by the redness of a bird's comb, such as fitness as a mate, then a fluorescent light that emits little

red light would hinder transmission of this visual cue. Incandescent luminaires, however, would allow efficient transmission. Third, artificial luminaires produce little, if any, UV_A radiation, which is biologically relevant in poultry species; its inclusion in conventional lighting along with other measures may help control feather pecking in turkey stags (Lewis *et al.*, 2000) and mediate mating behaviour and mate choice in broiler breeder fowl (Jones *et al.*, 2001).

Flicker Sensitivity

Flicker sensitivity is less well understood than spectral sensitivity. Both conventional and compact fluorescent luminaires flicker at either 100 or 120 Hz in Europe and North America, respectively. The light flux change is approximately symmetrically sinusoidal in response to the alternating current (AC) supply, but often becomes progressively less symmetrical as the luminaire is dimmed, which is possible for all conventional but only some compact luminaires. Using a psychophysical method, Nuboer *et al.* (1992b) found that some hens perceived blue light ($\lambda \approx 476$ nm) flickering up to 105 Hz but were less sensitive for other colours. The maximum frequencies perceived by humans are usually around 50–60 Hz (Brundrett, 1974). Recently, Jarvis *et al.* (2002) found that hens cannot detect 100 Hz flicker at 100 lx, but may be able to at much higher illuminances. In a tightly controlled experiment, Boshouwers and Nicaise (1992) found that at 90 lx, broilers exposed to 100 Hz flicker exhibited less 'activity' than controls exposed to 26 kHz. This finding is contrary to the work of Jarvis *et al.* (2002) but may reflect supra-threshold effects, significant deviations from sine-wave flicker or some other effect. At an illuminance of approximately 14 lx, however, Widowski and Duncan (1996) found that hens had no preference for fluorescent light flickering at a low (120 Hz) or high frequency (20–60 kHz). In two other studies, hens preferred dim fluorescent over dim incandescent lighting (Widowski *et al.*, 1992; Sherwin, 1999), although their preferences may have been influenced by the different colour characteristics of the light sources. From the limited information available, we see no reason to recommend a change from low to high frequency fluorescent lighting with respect to the bird's comfort, for two reasons. First, hens have no sensitivity to 100 Hz flicker at the illuminances and modulation depths typically found commercially. Second, three out of four preference tests showed no evidence of aversion, and the interpretation of the remaining one is not clear.

An interesting feature of the Jarvis *et al.* (2003) study is that the mechanistic modelling approach adopted allows the various components that combine to determine the hen's overall flicker sensitivity to be quantified and compared with other species. This study showed that, like all animals studied in such depth, the hen's sensitivity is characteristically 'tuned' to frequencies around 10 Hz, with decreasing sensitivity in either direction from this value (Fig. 15.2). It is difficult to understand why this tuning is so developed, but since flicker sensitivity is closely related to motion perception, it may be some artefact of that system.

Compared to humans, the generally reduced sensitivity at all frequencies indicates inferior post-retinal signal-to-noise performance. The comparable high frequency sensitivity indicates that the peripheral (retinal and optical) properties of the eye function similarly in this respect. The degree of tuning, higher for chickens than humans, and the preservation of high frequency sensitivity indicates an animal

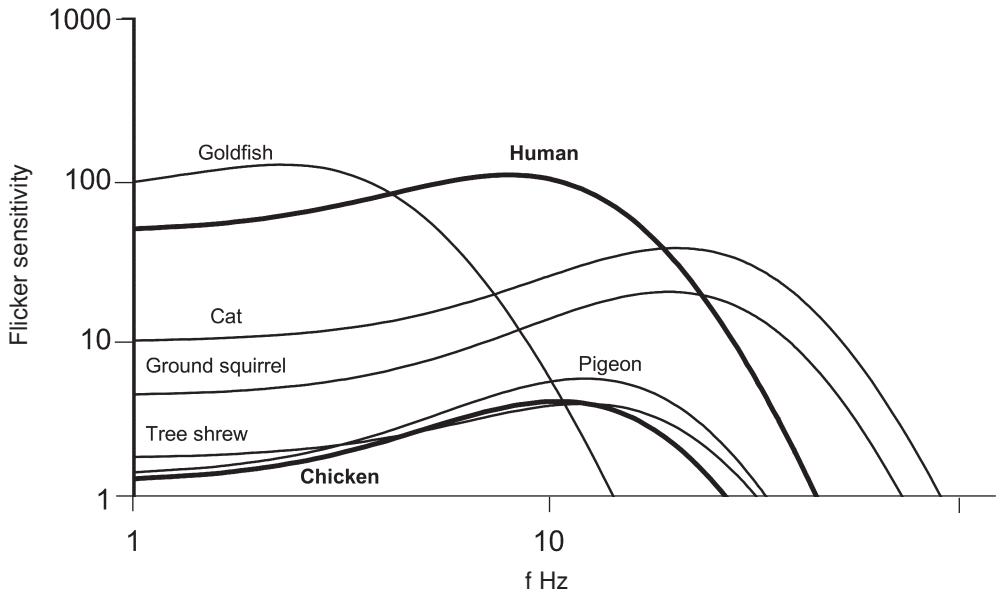

Fig. 15.2. Flicker sensitivity of a range of animal species (from Jarvis *et al.*, 2003 after the Barten (1999) model).

attuned to transience or movement in its visual environment, presumably a useful adaptation for one whose ancestors may have flown or who is predated upon by a wide array of predators.

Accommodation

In order to focus images on the retina, the eye must refract light rays. A greater degree of refraction is necessary to view near than distant objects: the degree to which an eye can adjust its refractive power is called the accommodative range (usually measured in dioptres, D). In poultry, because the eye is relatively small and the viewing distance is often very short (50–60 mm perhaps), the refraction of the eye must be very powerful if the image is to be clearly focused upon the retina. Two mechanisms may facilitate this. In humans and hens the lens can thicken via the action of the ciliary muscle, accounting for around a +8 D change in refractive power. In hens, but not humans, the cornea can also 'bulge', increasing the refractive power by a further +8 D (hens: Schaeffel and Howland, 1987; humans: Pugh, 1988).

In hens, accommodative range is enhanced by lower field myopia, allowing objects in this field to be focused upon the retina at small viewing distances, e.g. potential food items on the ground, as well as distant objects in the upper visual field, e.g. predators (Schaeffel *et al.*, 1994). This effect amounts to a difference between lower and upper field refractive power of around 8 D for 6-day-old chicks, declining to around 4 D by 28 days.

The interaction between lighting and accommodation is important because

light stimulation during rearing can affect the ability of the eye to accommodate. As animals grow, their eyes enlarge, which means that their refractive power must also change to maintain emmetropia (the absence of refractive error). One theory suggests that the regulation of eye growth is involved with diurnal rhythms of ocular elongation, perhaps mediated through the retinal neuromodulator dopamine (Nickla *et al.*, 1998). Abnormal photoperiods can cause very high refractive errors to appear in chickens (e.g. Stone *et al.*, 1995) as well as cataracts and other retinal damage. Clearly, poultry that are reared in conditions that could induce refractive error will be less able to extract important visual information from their surroundings. For example, they may be unable to navigate around a large poultry shed or recognize a threat in time to take evasive action. Equally, rearing environments that induce abnormal sensory development or damage are ethically questionable.

Spatial Acuity

Acuity is a measure of spatial resolution or the level of detail detected in visual images. It is determined largely by the clarity and precision of the optical system and the density of rod and cone cells in the retina. Acuity falls rapidly once the far and near limits of accommodation are exceeded. In chicken, acuity is poorer (e.g. DeMello *et al.*, 1992) than for humans (Spence, 1934). In crude terms, at the human's near-point (approx. 12.5 cm from the eye), black bars of 70 μm in diameter, and separated by 70 μm, could only just be resolved against a white background. At the hen's near-point (assumed to be approximately 5 cm), black bars of 170 μm diameter could just be discriminated. The two- or threefold better human acuity at the near-point reflects the action of the specialized fovea which, however, only accounts for a small fraction of the retina. Non-foveal acuity in humans falls rapidly as distance from the fovea increases. Hens also possess an area of high cone cell density (*area centralis*), that probably discerns detail, although it is less specialized than a fovea (Morris, 1982). This area has two extensions as mapped from the subserving ganglion cell density. The central extension receives images from just above the central point of that eye's hemispheric field of view (the central field) and may be used for detailed imaging of objects in the upper visual field, e.g. potential predators. The lateral extension extends from this, receiving images from a band running slightly downwards towards the beak (into the infero-frontal field), and it may image objects in the lower myopic field, e.g. food (Ehrlich, 1981). The limited reduction in ganglion cell density with increasing eccentricity from this region implies a less severe reduction in acuity than that encountered in humans. This may mean that although the maximum spatial acuity is very much higher for humans than hens, the mean spatial acuity around the whole field of view may be similar for the two species or even better for chickens. This, coupled perhaps with a much wider, focused visual field, suggests a radically different means of monitoring the environment.

Polarized Light Sensitivity

Light becomes polarized when the randomly oriented electric fields of the photons are selectively filtered. This occurs as unpolarized sunlight passes through

the earth's atmosphere or is reflected from a non-metallic shiny surface. Sensitivity to the polarization of light may help an animal to orient, since the pattern of polarization in the sky alters predictably as the position of the sun changes and is even visible through cloud (Land and Nilsson, 2002). Equally, the glare from water, wet or shiny surfaces can be reduced with a polarizing filter and this can aid the discrimination of cryptically hidden prey (Shashar *et al.*, 1998). Humans have no differential sensitivity to the orientation of polarized light, although good evidence exists for its presence in invertebrates. The evidence is more controversial in birds, e.g. Kreithen and Keeton's (1974) claim that pigeons are sensitive to polarization was not supported elsewhere (Vos Hzn *et al.*, 1995). It has been hypothesized that the double cone, ubiquitous amongst fish, reptiles, amphibians and birds, could offer a mechanism for the detection of polarized light (Cameron and Pugh, 1991). Artificially lit environments contain little polarized light, but if hens can be shown to possess such sensitivity then its inclusion in poultry sheds may confer some welfare advantage to them.

The Role of the Pupil

One role of the pupil is to control the light flux reaching the retina, which is mediated through mid-brain pathways. In hens, however, its role in controlling light flux seems relatively modest (Barbur *et al.*, 2002), with large changes in light flux generating only small changes in pupil size. The response, though, is approximately four times faster in chickens than humans, probably due to the 'fast', striated iris muscle type in birds versus the 'slow', smooth iris muscle in humans. In humans and other animals, however, there is also some control of pupil size through 'higher' pathways, e.g. fluctuations were reported in response to structure, colour and movement, independent of brightness changes (Barbur *et al.*, 1992) and can be seen in response to potent emotion (surprise, fear, lust). We do not know how the pupil changes in response to emotion but this evidence of higher-order control suggests that simple pupillometric techniques may be a readily quantifiable means of measuring the significance of visual stimuli to hens.

CONCLUSIONS

Light is an important stimulus in the confines of environmentally controlled hen houses. Although production consequences of various lighting regimes have been extensively studied, corresponding work on welfare of the hen is lacking. One concern is that current light environments may impose some sensory deprivation on the hen, rendering aspects of her vision redundant. The harmful consequences of brighter lighting on feather pecking and cannibalism are well known but it may be possible, with a better understanding of the hen's vision and of feather pecking, to provide light environments that minimize feather pecking while safeguarding other aspects of welfare. If hens could be reared under natural light, perhaps with some supplementation for those times of the year when the photoperiod is not conducive to development or laying, then most lighting concerns could be alleviated.

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REFERENCES

Andrew, R.J. and Dharmaretnam, M. (1993) Lateralization and strategies of viewing in the domestic chicken. In: Zeigler, H.P. and Bischof, H.-J. (eds) *Vision, Brain and Behavior in Birds*. MIT Press, Cambridge, Massachusetts, pp. 319–331.

Barbur, J.L., Harlow, A.J. and Sahraie, A. (1992) Pupillary responses to stimulus structure, colour and movement. *Ophthalmic and Physiological Optics* 12, 137–141.

Barbur, J.L., Prescott, N.B., Douglas, R., Jarvis, J.R. and Wathes, C.M. (2002) Stimulus-specific pupil responses in domestic chickens (*Gallus gallus domesticus*). *Vision Research* 42, 249–255.

Barten, P.J.G. (1999) *Contrast Sensitivity of the Human Eye and its Effects on Image Quality*. SPIE Optical Engineering Press, Washington, DC.

Boshouwers, F.M.G. and Nicaise, E. (1992) Responses of broiler chickens to high-frequency and low-frequency fluorescent light. *British Poultry Science* 33, 711–717.

Bowmaker, J.K. and Knowles, A. (1977) The visual pigments and oil droplets of the chicken retina. *Vision Research* 17, 755–764.

Brundrett, G.W. (1974) Human sensitivity to flicker. *Lighting Research and Technology* 6, 127–143.

Cameron, D.A. and Pugh, E.N. (1991) Double cones as a basis for a new type of polarization vision in vertebrates. *Nature* 353, 161–164.

Dartnall, H.J.A., Bowmaker, J.K. and Mollon, J.D. (1983) Human visual pigments: microspectrophotometric results from the eyes of seven persons. *Proceedings of the Royal Society of London, Series B* 220, 115–130.

DeMello, L.R., Foster, T.M. and Temple, W. (1992) Discriminative performance of the domestic hen in a visual acuity task. *Journal of the Experimental Analysis of Behaviour* 58, 147–157.

Ehrlich, D. (1981) Regional specialization of the chick retina as revealed by the size and density of neurons in the ganglion cell layer. *Journal of Comparative Neurology* 195, 643–657.

Günturkün, O. (1993) Functional anatomy of the avian visual system: introduction. In: Zeigler, H.P. and Bischof, H.-J. (eds) *Vision, Brain and Behavior in Birds*. MIT Press, Cambridge, Massachusetts, pp. 99–101.

Jarvis, J.R., Prescott, N.B. and Wathes, C.M. (2002) A mechanistic inter-species comparison of flicker sensitivity. *Vision Research* 43, 1723–1734.

Jarvis, J.R., Taylor, N.R., Prescott, N.B., Meeks, I. and Wathes, C.M. (2003) Measuring and modelling the photopic flicker sensitivity of the chicken (*Gallus g. domesticus*). *Vision Research* 42, 99–106.

Jones, E.K.M., Prescott, N.B., Wathes, C.M. and Cook, P. (2001) The role of UV_A light in mating behaviour and mate choice by domestic broiler breeders, *Gallus gallus domesticus*. *British Poultry Science* 42, 23–32.

King-Smith, P.E. (1971) Special senses. In: Bell, D.J. and Freeman, B.M. (eds) *Physiology and Biochemistry of the Domestic Fowl,* Vol. 2. Academic Press, London, pp. 1039–1083.

Kreithen, M.L. and Keeton, W.T. (1974) Detection of polarized light by the homing pigeon, *Columba livia*. *Journal of Comparative Physiology* 89, 83–92.

Land, M.F. and Nilsson, D.-E. (2002) *Animal Eyes*. Oxford University Press, New York.

Lewis, P.D., Perry, G.C. and Sherwin, C.M. (2000) Effect of ultra-violet radiation on the performance of intact male turkeys. *Poultry Science* 79, 850–855.

Martin, G.R. (1982) An owl's eye: schematic optics and visual performance in *Strix aluco* L. *Journal of Comparative Physiology* 145, 341–349.

Martin, G.R. (1993) Producing the image. In: Zeigler, H.P. and Bischof, H.-J. (eds) *Vision, Brain and Behavior in Birds.* MIT Press, Cambridge, Massachusetts, pp. 5–24.

Morris, V.B. (1982) An afoveate area centralis in the chick retina. *Journal of Comparative Neurology* 210, 198–203.

Nickla, D.L., Wildsoet, C. and Wallman, J. (1998) Visual influences on diurnal rhythms in ocular length and choroidal thickness in chick eyes. *Experimental Eye Research* 66, 163–181.

Nuboer, J.F.W., Coemans, M.A.J.M. and Vos, J.J. (1992a) Artificial lighting in poultry houses: are photometric units appropriate for describing illumination intensities? *British Poultry Science* 33, 135–140.

Nuboer, J.F.W., Coemans, M.A.J.M. and Vos, J.J. (1992b) Artificial lighting in poultry houses: do hens perceive the modulation of fluorescent lamps as flicker? *British Poultry Science* 33, 123–133.

Osorio, D., Vorobyev, M. and Jones, C.D. (1999) Colour vision of domestic chicks. *Journal of Experimental Biology* 202, 2951–2959.

Prescott, N.B. and Wathes, C.M. (1999) Spectral sensitivity of the domestic fowl (*Gallus g. domesticus*). *British Poultry Science* 40, 332–339.

Prescott, N.B., Jarvis, J.R. and Wathes, C.M. (2003) Light, vision and the welfare of poultry. *Animal Welfare* 12, 269–288.

Pugh, E.N. (1988) Vision: physics and retinal physiology. In: Atkinson R.C., Herrnstein R.J., Lindzey, G. and Luce, R.D. (eds) *Stevens' Handbook of Experimental Psychology.* Vol. 1: *Perception and Motivation*. Wiley, New York.

Rashid, N. and Andrew, R.J. (1989) Right hemisphere advantage for topographical orientation in the domestic chicken. *Neuropsychologia* 27, 937–948.

Schaeffel, F. and Howland, H.C. (1987) Corneal accommodation in the chick and pigeon. *Journal of Comparative Physiology A* 160, 375–384.

Schaeffel, F., Hagel, G., Eikermann, J. and Collett, T. (1994) Lower-field myopia and astigmatism in amphibians and chickens. *Journal of the Optical Society of America* 11, 487–495.

Shashar, N., Cronin, T.W., Wolff, L.B. and Condon, M.A. (1998) The polarization of light in a tropical rain forest. *Biotropica* 30, 275–285.

Sherwin, C.M. (1999) Domestic turkeys are not averse to compact fluorescent lighting. *Applied Animal Behaviour Science* 64, 47–55.

Spence, K.W. (1934) Visual acuity and its relation to brightness in chimpanzee and man. *Journal of Comparative Physiology* 18, 333–361.

Stone, R.A., Lin, T., Desai, D. and Capehart, C. (1995) Photoperiod, early post-natal eye growth, and visual deprivation. *Vision Research* 35, 1195–1202.

Vallortigara, G. and Andrew, R.J. (1991) Lateralization of response by chicks to change in model partner. *Animal Behaviour* 41, 187–194.

Vos Hzn, J.J., Coemans, M.A.J.M. and Nuboer, J.F.W. (1995) No evidence for polarization sensitivity in the pigeon electroretinogram. *Journal of Experimental Biology*, 198, 325–335.

Widowski, T.M. and Duncan, I.J.H. (1996) Laying hens do not have a preference for high-frequency versus low-frequency compact fluorescent light sources. *Canadian Journal of Animal Science* 76, 177–181.

Widowski, T.M., Keeling, L.J. and Duncan, I.J.H. (1992) The preferences of hens for compact fluorescent over incandescent lighting. *Canadian Journal of Animal Science* 72, 203–211.

Workman, L. and Andrew, R.J. (1989) Simultaneous changes in behaviour and in laterization during the development of male and female domestic chicks. *Animal Behaviour* 38, 596–605.

Yoshizawa, T. (1992) The road to colour vision: structure, evolution and function of chicken and gecko visual pigments. *Photochemistry and Photobiology* 56, 859–867.

CHAPTER 16
Pain and the laying hen

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ABSTRACT

Pain in animals can best be defined as 'an aversive sensory experience caused by actual or potential injury that elicits protective motor and vegetative reactions, results in learned avoidance, and may modify species-specific behaviour, including social behaviour'. Freedom from pain is essential for animal welfare. The ability to respond in an appropriate manner to aversive environmental stimuli is a basic characteristic of animals. Noxious stimuli excite cutaneous receptors (nociceptors), leading to reflex or non-reflex behavioural responses. While nociceptor activity cannot in isolation be considered indicative of pain, there is a clear relationship between nociceptor responses and pain experienced in humans. In animal studies of pain, it is necessary to combine nociceptive information with a range of behavioural and physiological measurements in order to estimate the probability of pain. In the life of a modern commercial hen, pain is likely to arise from acute traumatic injury caused by shackling, beak trimming or skeletal fracture, or from chronic pain caused by disease.

Nociceptors, the most common of which were mechanothermal nociceptors, have been identified and physiologically characterized in the chicken beak, wattles, scaly skin, joints, mouth and nasal cavity. These send information to the CNS via small unmyelinated nerve fibres (C-fibres) and have differing properties according to location; those in the beak have lower thermal but higher mechanical thresholds than those in the scaly skin. A second group of mechanothermal nociceptors, the small myelinated A-delta fibres, occur in both the scaly skin and joints of the chicken and are similar to those only previously reported in the hairy skin of humans and primates. The combination of these nociceptors is thought to be responsible for a double pain sensation; the A-delta fibres being responsible for the immediate pain sensation and rapid reflex response to the stimulus while the second, qualitatively different pain sensation modulated by the slower C-fibres would prevent repetition. The nociceptors in the chicken ankle joint show little spontaneous activity or response to normal flexion or extension but respond to excessive lateral or rotational movements, thus serving as protection against joint damage.

The forces applied to the legs of chickens during shackling have been shown to exceed the mechanical threshold required to excite the C-fibre mechanothermal nociceptors in the skin of the leg. Stimulus response curves for these nociceptors demonstrated that the maximum response in 63% of these was below the force applied in shackling, providing evidence that the process is likely to be painful.

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The initial pain resulting from beak trimming probably lasts for between 2 and 48 s and is followed by a pain-free period of several hours. Thereafter, the painful consequences of beak trimming vary according to the age at which the procedure was conducted. If beak trimming occurs before 10 days of age, pain-related behavioural changes do not occur immediately; pecking is not reduced 6 h post-procedure but is reduced significantly by 26 h. Beak trimming in adults has more pronounced effects. Both beak-related and non-beak-related activities are affected for at least 5 weeks post-procedure. Electrophysiological recordings from the beak stump support this; in the weeks following beak trimming, large numbers of spontaneously active nerve fibres were recorded. There was no beak regeneration and extensive neuroma formation was observed adjacent to the scar tissue at the end of the beak.

While skeletal fracture is common in laying hens, and pain following fracture in humans is common, there is no published information on the electrophysiological or behavioural responses to fracture. In view of the proposed ban on conventional cages, and with the fact that skeletal fracture is more common in aviary systems, there is a clear requirement for research on the welfare consequences of fracture in laying hens.

Although widespread spontaneous arthropathies leading to loss of locomotor function are more common in meat-type poultry than layers, the latter do develop gout, bacterial and mycoplasma infections. The painful consequences of these conditions in the chicken have been investigated in experiments involving intra-articular injection of sodium urate or mycoplasma. After the injection of sodium urate, joint capsule C-fibre nociceptors became sensitized and birds exhibited behavioural changes indicative of pain, including one-legged standing, limping and sitting dozing, but rapidly returned to normal following the injection of local anaesthetic into the treated joint. Injection of killed *Mycobacterium tuberculosis* into the ankle joint produced a severe inflammatory arthropathy with a pronounced synovitis together with destructive cartilage damage. Recordings from the sensory receptors in the ankle joint showed that they were clearly sensitized and that inflammatory arthropathies found in the chicken are likely to be painful. This technique, when combined with quantitative gait analysis, showed that histological and electrophysiological changes were accompanied by a quantifiable, severe limp in the early stages (7–21 days after infection). At the more chronic stage of the disease (49–56 days after infection), while pathological changes were still observed in the joint capsule, the sensory fibres responded normally to mechanical stimulation and joint movement, and gait analysis showed that the birds were not lame.

INTRODUCTION

Freedom from pain is essential for animal welfare, and this is especially important in the laying hen when large numbers of animals are kept for long periods of time in intensive husbandry conditions. The ability to respond in an appropriate manner to aversive environmental stimuli is a basic characteristic of animals. Noxious stimuli excite cutaneous receptors, which are preferentially sensitive to tissue-damaging, or potentially tissue-damaging, stimuli and are referred to as nociceptors. Their stimulation leads to reflex behaviour (Sherrington, 1947) or non-reflex behavioural responses. The activity induced in nociceptors or in nociceptive neural pathways should not always be considered as indicative of pain, but recordings from cutaneous nociceptors in humans have shown a clear relationship between the neural responses of cutaneous nociceptors and the pain experienced (Torebjörk *et al.*, 1996). Pain has been defined by the International Association for the Study of Pain (IASP, 1979) as: 'An unpleasant sensory and emotional

experience associated with actual or potential tissue damage or described in terms of such damage'. Pain, therefore, is always subjective and, while it is a sensation in part of the body, it is also an emotional experience. The subjective nature of pain makes it a difficult concept to apply to animals because of the problem of animal awareness and conscious feelings associated with it. Recent work in the chicken (Gentle, 2001) has, however, provided information about the cognitive perception of pain as well as evidence for consciousness. The detection and assessment of pain in the bird does present a number of difficulties, not least of which is that there is no universal indicator of pain. What can be done, however, is to compare a range of physiological and behavioural measures with those changes associated with pain in humans, and thereby arrive at an estimate of the probability of pain in any given situation. Zimmermann (1986) proposed a working definition of pain in animals as:

> An aversive sensory experience caused by actual or potential injury that elicits protective motor and vegetative reactions, results in learned avoidance, and may modify species-specific behaviour, including social behaviour.

This definition is not sufficiently comprehensive to help us to unambiguously determine whether or not an animal is in pain, but it minimizes subjectivity and provides a framework for experimental studies of pain detection. The results of such studies can be used to assess the painful consequences of current husbandry practices.

This chapter summarizes current behavioural and physiological evidence for acute and chronic pain following traumatic injury and disease, together with pain modulation through the use of analgesic drugs and endogenous mechanisms.

ACUTE TRAUMATIC INJURY

Nociceptors have been identified and physiologically characterized in a number of different locations in the body of the chicken, including the beak (Gentle, 1989), joints (Gentle, 1992), wattles (Gentle and Hunter, 1993), scaly skin (Gentle *et al.*, 2001), mouth (Gentle, 1979) and nasal cavity (McKeegan *et al.*, 2002). The most common type of nociceptor encountered in cutaneous tissues was the mechanothermal (polymodal) nociceptor. These receptors send their information to the central nervous system in small nerve fibres lacking a myelin sheath (C-fibres), probably arising from cutaneous free-nerve endings. They respond to both mechanical deformation of the skin and heating by giving a slowly adapting response. There also appears to be some functional specialization in that polymodal nociceptors have different properties in different areas of the body. For example, those in the beak have lower thermal thresholds but higher mechanical thresholds than those in the scaly skin of the leg (Gentle *et al.*, 2001). In general, however, mechanothermal nociceptors found in the chicken have physiological properties which are similar to nociceptors found in mammals (Beck *et al.*, 1974; Beitel and Dubner, 1976; Lynn and Carpenter, 1982; Treede *et al.*, 1995; Garell *et al.*, 1996).

More recently, a second group of mechanothermal nociceptors were identified in the scaly skin (Gentle *et al.*, 2001), which consisted of small myelinated nerve fibres (A-delta fibres) with similar properties to the A-delta mechanothermal nociceptors that have previously only been reported in the hairy skin of humans and

primates (Campbell and LaMotte, 1983; Torebjörk *et al*., 1996). The presence of A-delta mechanothermal nociceptors in the bird has implications for the possible pain experienced by the animal. In man, heat stimuli evoke a double pain sensation, with the first sensation being felt as a sharp pricking and the second as a burning feeling (Lewis and Pochin, 1937; Campbell and LaMotte, 1983). The latency to respond to first pain is too quick to be carried by the slowly conducting C-fibres, and so the A-delta fibres are thought to signal first pain. The presence of similar fibres in the chicken raises the possibility of double pain. The A-delta nociceptors would be responsible for the leg withdrawal reflex, with an obvious function of maintaining the integrity of the leg. The second pain, modulated by the C-fibres, would be qualitatively different and would prevent the animal from repeating the damaging action, thus reducing motility and promoting resting and healing.

Both C- and A-delta fibre nociceptors have been identified in the ankle joint of the chicken (Gentle, 1992); they respond to mechanical stimulation of the joint capsule but show little or no response to normal joint movement. If, however, the joint is moved in a noxious range, especially lateral or rotational movements, then these receptors respond with a prolonged, slowly adapting discharge. Like all nociceptors, they show little or no spontaneous activity. These nociceptors therefore do not signal movements of flexion or extension but rather signal rotational or extreme lateral movements for which the joint is not designed and which could result in joint damage.

Shackling

The shackling of commercial poultry prior to slaughter involves the insertion of each leg into parallel metal slots and holding the bird inverted for a time. Sparrey (1994) calculated that the resultant force on each leg of the bird, when inserted into the shackle, could be 180 N applied over an area of 1 cm^2. In broiler birds the pressure required to compress the legs into shackles increases exponentially with deformation and it requires four times as much pressure to compress a 14.5 mm diameter leg by 20% to fit into a 11.5 mm shackle, as it does to compress the same leg by 10% to fit into a 13 mm shackle. These forces acting over relatively small areas of the leg may cause pain and distress to the bird (Sparrey and Kettlewell, 1994). Measurement of the mechanical thresholds required to excite the C-fibre mechanothermal nociceptors in the skin of the leg showed that all of them responded below the forces present during shackling. Stimulus response curves were obtained for a number of these receptors and in 63% of the fibres tested the maximum response was below the force applied in shackling. In conclusion, this level of activity in peripheral nociceptors would mean that shackling is likely to be very painful (Gentle and Tilston, 2000).

Beak trimming

The partial amputation of the chicken's beak (beak trimming), which is accomplished by a combination of cutting and cautery, is performed in commercially reared poultry to prevent or control cannibalism and feather pecking.

Acute pain following beak trimming

The initial pain resulting from the beak removal probably only lasts for about 2–48 s (Gentle, 1991) and this is followed by a pain-free period lasting several hours (Gentle *et al*., 1991). Any prolonged painful effect of beak trimming depends on the age at which the birds are trimmed. In an experiment where birds were trimmed at 1 or 10 days of age, all of the beaks healed quickly, no scar tissue was seen, and there was extensive regeneration of the beak tissue (Gentle *et al*., 1997). In the first week after trimming there were some significant behavioural changes observed but these differences were not large or consistent. For example, trimmed birds were seen sitting/sleeping more often than control birds but there were no differences in standing or walking and beak-related behaviours were very variable (Gentle *et al*., 1997).

Pain-related behaviours do not develop immediately after trimming. Beak guarding behaviour was measured by counting the number of pecks the birds delivered to an attractive visual stimulus before and again 6, 26 and 32 h after beak trimming (Gentle *et al*., 1991). At 6 h after trimming the birds continued to peck the same number of times at the stimulus but by 26 h after trimming there was a significant reduction in pecking. These results indicated a pain-free period of several hours immediately after trimming and this was confirmed by physiological evidence. Electrophysiological recordings from sensory nerve fibres in the beak, during and immediately after trimming with a heated blade, has shown that just before the blade makes contact with the beak the sensory fibres begin to respond (Gentle, 1991). During beak removal and for a period of 2–48 s after removal there was a massive injury discharge in the nerve fibres, which is likely to be responsible for the acute pain experienced at the time of removal. For several hours after this injury discharge there was no further abnormal neural activity in the nerve running to the amputated beak stump. This probably explains the pain-free period observed in the behavioural experiments. Similar pain-free periods are seen in humans after major traumatic burn injuries especially after full-thickness burns (Stein and Stein, 1983; Robertson *et al*., 1985).

Chronic pain following beak trimming

Beak trimming in adult hens presents a very different picture to trimming in young chicks. Behavioural changes, which could be interpreted as indicative of chronic pain, have been observed for long periods after trimming. For at least 5 weeks after trimming there was a significant reduction in the use of the beak for non-essential activities such as preening and exploratory pecking (Duncan *et al*., 1989). Other non-beak-related activities were also affected, with the birds showing persistent increases in time spent inactive (Duncan *et al*., 1989). Eskeland (1981) also observed inactivity and dozing but these results extended to 56 weeks after surgery. Further evidence of pain-related beak guarding behaviour such as reductions in environmental pecking, beak wiping and head shaking comes from a study where the birds were presented with drinking water ranging in temperature from 20 to 45°C (Gentle *et al*., 1990).

In addition to this behavioural evidence of guarding the painful stump of the beak, there is physiological and anatomical evidence to support possible chronic pain after beak trimming. Electrophysiological recordings from the nerves running to the stump of the beak in the days and weeks following trimming show abnormal features (Breward and Gentle, 1985). The most characteristic abnormality

encountered was the presence of large numbers of spontaneously active nerve fibres. This spontaneous activity was similar to that observed in experimental neuroma preparations (Wall and Gutnick, 1974; Govrin-Lippmann and Devor, 1978; Scadding, 1981; Devor and Bernstein, 1982; Blumberg and Janig, 1984) and is thought to be the basis for stump pain. In the healed beaks of birds beak-trimmed as adults there was no beak regeneration and adjacent to the scar tissue at the end of the beak there was extensive neuroma formation (Gentle, 1986). It is likely, therefore, that these neuromas are responsible for the abnormal neural activity seen in the afferent nerve fibres.

Skeletal Fracture

Osteoporosis and subsequent bone fracture in hens has been recognized as a welfare issue for at least 15 years (Randall and Duff, 1988). The proposed cage ban may exacerbate the problem because it has been demonstrated that perchery systems result in a higher incidence of fractures than conventional cages (Gregory *et al*., 1990). Although pain following bone fracture is common in humans (Yates and Smith, 1995), the pathophysiology of the pain (particularly the responses of orthopaedic nociceptors after injury) is not well understood. In poultry it is commonly found that humeral bone fracture is identified at post-mortem examination despite no observed pain-related behaviour. There are no published descriptions of pain-related behaviour following fracture in poultry. This absence of a clear behavioural response following fracture cannot be taken as an indication that the birds are not in pain because nocifensive behaviours can often take the form of behavioural immobility (Woolley and Gentle, 1987; Gentle and Hunter, 1990), and handling or moving the birds will produce major attentional shifts in the animals, thereby altering pain perception (Gentle, 2001).

Nociceptive information could arise from a number of tissues following fracture: surrounding soft tissue, periosteum and bone. Damage to soft tissue would be variable across skeletal sites following fracture, but all fractures affect the bone and periosteum. Pain has been reported upon manipulation of the periosteum in human subjects following bone injury (Weddell and Harpman, 1940; Houghton *et al*., 1997). In mammals, bone and periosteum receive sensory nerves (Gronblad *et al*., 1984; Hukkanen *et al*., 1992). Although there is no information on the neural innervation of the bone and periosteum in the chicken, because of the similarities between avian and mammalian cutaneous and articular nociceptors (Gentle, 1991; Gentle *et al*, 2001) there is no reason to believe that they will be fundamentally different.

DISEASE AND CHRONIC PAIN

Disease

Widespread spontaneous arthropathies leading to a loss of locomotor function are common in heavy breeds of domestic poultry but are less common in laying hens. Laying hens do, however, develop gout as well as bacterial and mycoplasma infections and are thus likely to suffer pain as a result of orthopaedic disease.

Gout

Articular gout is a disease characterized by the deposition of sodium urate crystals in the joint cavity. In humans this is a severely painful condition but until recently its painful nature in the chicken had not been investigated in detail. Intra-articular injection of microcrystal sodium urate mimics gout arthritis and has been used to investigate the disease in humans (Seegmiller *et al.*, 1962), other mammals (Coderre and Wall, 1988) and birds (Brune *et al.*, 1974; Gentle and Corr, 1995). Shortly after the injection of sodium urate into the ankle, chickens lifted the injected leg and stood on the uninjected one. For a 3-h period after injection the birds spent most of their time sitting and dozing and they appeared hypoaesthetic, with drooping head and tail, ruffled feathers, few head movements and the eyes intermittently closed. In this condition they were unwilling to stand or walk, and if encouraged to do so, they staggered and were reluctant to put any weight on the injected leg (Gentle and Corr, 1995). One-legged standing, limping and sitting dozing are clear examples of pain-related behaviours and the animal will return rapidly to normal following the injection of local anaesthetic into the treated joint (Hocking *et al.*, 1997). Electrophysiological recordings from the joint capsule C-fibre nociceptors showed that they become sensitized following urate injection (Gentle, 1997). The high level of spontaneous activity in these receptors would explain the continuous nature of the pain resulting in the long periods of resting. The increased response of these receptors to joint movement and mechanical stimulation would increase pain on movement and explain the severe lameness, standing on one leg and their reluctance to place any weight on the affected joint. These findings indicate that gouty arthritis is a very painful condition in the bird.

Infectious arthritis

Evidence for the painful nature of bacterial infections comes from a study where a limited non-infectious model of bacterial infection was produced by injecting killed *Mycobacterium tuberculosis* into the ankle joint. This model produced a cellular response to the bacterium, resulting in a severe inflammatory arthropathy with a pronounced synovitis together with destructive cartilage damage. Recordings from the sensory receptors in the ankle joint showed that they were clearly sensitized and that inflammatory arthropathies found in the chicken are likely to be painful (Gentle and Thorp, 1994).

A recent multidisciplinary study was conducted to investigate the painful consequences of mycoplasma arthritis (Gentle *et al.*, 2003). This study involved the induction of mycoplasma arthritis by injecting the microorganism directly into the ankle, with the disease being restricted to this joint (Morrow *et al.*, 1997). The electrical activity of the nociceptors was recorded in the ankle and was combined with both a detailed histopathological analysis of the joint and quantitative gait analysis. The disease was investigated during its early stages (7–21 days after infection) as well as the more chronic stage of the disease (49–56 days after infection). During the early stage of the disease there was histopathological evidence of acute synovitis and the nociceptors showed sensitization. This sensitization is likely to produce pain; this is supported by the reluctance of the birds to place any weight on the infected joint and the bird showing a quantifiable, severe limp. In the chronic stage of the disease there was a chronic synovitis with a thick layer of hypertophic and hyperplastic synoviocytes together with lymphoid nodules, but the sensory fibres responded normally to mechanical stimulation and joint movement.

The absence of any sensitization during this chronic stage would suggest an absence of pain when the disease might be in a period of remission. The absence of pain during this chronic stage was also supported by the gait analysis data; the birds did not show any unilateral lameness. The absence of a clear relationship between synovial pathology and sensitization of nociceptors in the acute stage of the disease and the normal physiological responses of these receptors in chronic prolonged synovitis indicates the difficulties associated with predicting nociceptive consequences in animals on the basis of histopathology.

ANALGESIA

Anti-inflammatory drugs have been used in tonic models of articular pain (Benzi *et al*., 1966; Floersheim *et al*., 1973; Brune *et al*., 1974) and optimum dose rates for the more commonly used steroid drugs have been established for the chicken (Hocking *et al*., 2001). Opioid analgesics have been investigated in a number of studies using reflex withdrawal behaviour evoked by a brief noxious stimulus (Fan *et al*., 1981; Hughes, 1990; Sufka and Hughes, 1990, 1992) as well as a tonic model of articular pain (Gentle *et al*., 1999).

The laying hen has very effective endogenous pain-modulating mechanisms. Experimental sodium urate arthritis produced quantifiable pain-related behaviours when the birds were tested in their cage (Gentle and Corr, 1995) but changes in motivation reduced these pain behaviours. It has been hypothesized that these motivational changes diverted attention away from the pain. The motivational changes investigated included nesting, feeding, exploration and social interactions. The degree of pain suppression ranged from marked hypoalgesia to complete analgesia and as such demonstrated the remarkable ability of the chicken to suppress tonic pain (Gentle, 2001). It was also found that these shifts in attention not only reduced pain but also reduced peripheral inflammation (Gentle and Tilston, 1999). The fact that attentional shifts can alter pain perception would indicate a cognitive component of pain in the chicken and provides evidence of consciousness. The implication for the welfare of the bird is that the pain they experience may have some of the complex facets of pain normally only ascribed to pain in humans.

REFERENCES

Beck, P.W., Handwerker, H.O. and Zimmermann, M. (1974) Nervous outflow from the cat's foot during noxious radiant heat stimulation. *Brain Research* 67, 373–386.

Beitel, R.E. and Dubner, R. (1976) Responses of (C) polymodal nociceptors to thermal stimuli applied to monkey's face. *Journal of Neurophysiology* 39, 1160–1175.

Benzi, G., Crema, A. and Frigo, G.M. (1966) Action of some drugs on the 'one-footed position test' in the pigeon. *Journal of Pharmaceutical Science* 54, 1689–1690.

Blumberg, J. and Janig, W. (1984) Discharge pattern of afferent fibres from a neuroma. *Pain* 20, 335–353.

Breward, J. and Gentle, M.J. (1985) Neuroma formation and abnormal afferent nerve discharges after partial beak amputation (beak trimming) in poultry. *Experientia* 41, 1132–1134.

Brune, K., Walz, D. and Bucher, K. (1974) The avian microcrystal arthritis. I. Simultaneous recording of nociception and temperature effect in the inflamed joint. *Agents Actions* 4, 21–26.

Campbell, J.N. and LaMotte, R.H. (1983) Latency to detection of first pain. *Brain Research* 266, 203–208.

Coderre, T.J. and Wall, P.D. (1988) Ankle joint urate arthritis in rats provides a useful tool for the evaluation of analgesic and anti-arthritic agents. *Pharmacology Biochemistry and Behaviour* 29, 461–466.

Devor, M. and Bernstein, J.J. (1982) Abnormal impulse generation in neuromas: electrophysiology and ultrastructure. In: Culp, W.J. and Ochoa, J. (eds) *Abnormal Nerves and Muscles as Impulse Generators*. Oxford University Press, Oxford, pp. 363–380.

Duncan, I.J.H., Slee, G.S., Seawright, E. and Breward, J. (1989) Behavioural consequences of partial beak amputation (beak trimming) in poultry. *British Poultry Science* 30, 479–489.

Eskeland, B. (1981) Effects of beak trimming. In: Sorensen, L.Y. (ed.) *First European Symposium on Poultry Welfare.* Danish Branch of the World Poultry Science Association, Copenhagen, pp. 193–200.

Fan, S.G., Shutt, A.J. and Vogt, M. (1981) The importance of 5-hydroxytryptamine turnover for the analgesic effect of morphine in the chicken. *Neuroscience* 6, 2223–2227.

Floersheim, G.L., Brune, K. and Seiler, K. (1973) Colchicine in avian sodium urate and calcium pyrophosphate microcrystal arthritis. *Agents Actions* 3, 20–23.

Garell, P.C., McGillis, S.L.B. and Greenspan, J.D. (1996) Mechanical response properties of nociceptors innervating feline hairy skin. *Journal of Neurophysiology* 75, 1177–1189.

Gentle, M.J. (1979) Single unit responses from the solitary complex following oral stimulation in the chicken. *Journal of Comparative Physiology* 130, 259–264.

Gentle, M.J. (1986) Neuroma formation following partial beak amputation (beak trimming) in the chicken. *Research in Veterinary Science* 41, 383–385.

Gentle, M.J. (1989) Cutaneous sensory afferents recorded from the nervus intramandibularis of *Gallus gallus* var *domesticus*. *Journal of Comparative Physiology A* 164, 763–774.

Gentle, M.J. (1991) The acute effects of amputation on peripheral trigeminal afferents in *Gallus gallus* var *domesticus*. *Pain* 46, 97–103.

Gentle, M.J. (1992) Ankle joint (artc. intertarsalis) receptors in the domestic fowl. *Neuroscience* 49, 991–1000.

Gentle, M.J. (1997) Sodium urate arthritis: effects on the sensory properties of articular afferents in the chicken. *Pain* 70, 245–251.

Gentle, M.J. (2001) Attentional shifts alter pain perception in the chicken. *Animal Welfare* 10, S187–S194.

Gentle, M.J. and Corr, S.A. (1995) Endogenous analgesia in the chicken. *Neuroscience Letters* 201, 211–215.

Gentle, M.J. and Hunter, L.N. (1990) Physiological and behavioural responses associated with feather removal in *Gallus gallus* var *domesticus*. *Research in Veterinary Science* 50, 95–101.

Gentle, M.J. and Hunter, L.N. (1993) Neurogenic inflammation in the chicken (*Gallus gallus* var *domesticus*). *Comparative Biochemistry and Physiology* 105C, 459–462.

Gentle, M.J. and Thorp, B.H. (1994) Sensory properties of ankle joint capsule mechanoreceptors in acute monoarthritic chickens. *Pain* 57, 361–374.

Gentle, M.J. and Tilston, V.L. (1999) Reduction in peripheral inflammation by changes in attention. *Physiology and Behaviour* 66, 289–292.

Gentle, M.J. and Tilston, V.L. (2000) Nociceptors in the legs of poultry: implications for potential pain in pre-slaughter shackling. *Animal Welfare* 9, 227–236.

Gentle, M.J., Waddington, D., Hunter, L.N. and Jones, R.B. (1990) Behavioural evidence for persistent pain following partial beak amputation in chickens. *Applied Animal Behaviour Science* 27, 149–157.

Gentle, M.J., Hunter, L.N. and Waddington, D. (1991) The onset of pain related behaviours following partial beak amputation in the chicken. *Neuroscience Letters* 128, 113–116.

Gentle, M.J., Hughes, B.O., Fox, A. and Waddington, D. (1997) Behavioural and anatomical consequences of two beak trimming methods in 1- and 10-d-old domestic chicks. *British Poultry Science* 38, 453–463.

Gentle, M.J., Hocking, P.M., Bernard, R. and Dunn, L.N. (1999) Evaluation of intraarticular opioid analgesia for the relief of articular pain in the domestic fowl. *Pharmacology Biochemistry and Behaviour* 63, 339–343.

Gentle, M.J., Tilston, V. and McKeegan, D.E.F. (2001) Mechanothermal nociceptors in the scaly skin of the chicken leg. *Neuroscience* 106, 643–652.

Gentle, M.J., Bradbury, J.M. and Wilson, S. (2003) Sensory properties of articular afferents following Mycoplasma arthritis in the chicken. *Brain Research* 968, 26–34.

Govrin-Lippmann, R. and Devor, M. (1978) Ongoing activity in severed nerves: source and variation with time. *Brain Research* 159, 406–410.

Gregory, N.G., Wilkins, L.J., Eleperuma, S.D., Ballantyne, A.J. and Overfield, N.D. (1990) Broken bones in domestic fowl. *British Poultry Science* 31, 59–69.

Gronblad, M., Liesi, P., Korkala, O., Karaharju, E. and Polak, J. (1984) Innervation of human bone periosteum by peptidergic nerves. *Anatomical Record* 209, 297–299.

Hocking, P.M., Gentle, M.J., Bernard, R. and Dunn, L.N. (1997) Evaluation of a protocol for determining the effectiveness of pre-treatment with local anaesthetics for reducing experimentally induced articular pain in domestic fowl. *Research in Veterinary Science* 63, 263–267.

Hocking, P.M., Robertson, G.W. and Gentle, M.J. (2001) Effects of anti-inflammatory steroid drugs on pain coping behaviours in a model of articular pain in the domestic fowl. *Research in Veterinary Science* 71, 161–166.

Houghton, A.K., Hewitt, E. and Westlund, L.N. (1997) Enhanced withdrawal responses to mechanical and thermal stimuli after bone injury. *Pain* 73, 325–337.

Hughes, R.A. (1990) Strain-dependent morphine-induced analgesia and hyperalgesic effects on thermal nociception in domestic fowl (*Gallus gallus*). *Behavioural Neuroscience* 104, 619–624.

Hukkanen, M., Konttinen, Y.T., Rees, R.G., Santavirta, S., Terenghi, G. and Polak, J.M. (1992) Distribution of nerve endings and sensory neuropeptides in rat synovium, meniscus and bone. *International Journal of Tissue Reactions* 15, 1–10.

IASP (1979) International Association for the Study of Pain, sub-committee on taxonomy. Pain terms: a list with definitions and notes on usage. *Pain* 6, 249–252.

Lewis, T. and Pochin, E.E. (1937) The double pain response in the human skin to a single stimulus. *Clinical Science* 3, 67–76.

Lynn, B. and Carpenter, S.E. (1982) Primary afferent units from the hairy skin of the rat hind limb. *Brain Research* 238, 29–43.

McKeegan, D.F., Demmers, T.G.M., Wathes, C.M., Jones, R.B. and Gentle, M.J. (2002) Response characteristics of nasal trigeminal nociceptors in *Gallus domesticus*. *NeuroReport* 13, 1033–1035.

Morrow, C.J., Bradbury, J.M., Gentle, M.J. and Thorp, B.H. (1997) The development of lameness and bone deformity in the broiler following experimental infection with *Mycoplasma gallisepticum* or *Mycoplasma synoviae*. *Avian Pathology* 26, 169–187.

Randall, C.J. and Duff, S.R.I (1988) Avulsion of the patellar ligament in osteopenic laying fowl. *Veterinary Record* 123, 439–441.

Robertson, K.E., Cross, P.J. and Terry, J.C. (1985) The crucial first days. *American Journal of Nursing* 85, 30–47.

Scadding, J.W. (1981) Development of ongoing activity, mechanosensitivity, and adrenaline sensitivity in severed peripheral axons. *Experimental Neurology* 73, 345–364.

Seegmiller, J.E., Howell, R.R. and Malaista, S.E. (1962) The inflammatory reaction to sodium urate. *Journal of the American Medical Association* 180, 469–475.

Sherrington, C. (1947) *The Integrative Action of the Nervous System*, 2nd edn. Yale University Press, New Haven, Connecticut, pp. 227–232.

Stein, J.M. and Stein, E.D. (1983) Pain management. In: Bernstein, N.R. and Robson, M.C. (eds) *Comprehensive Approaches to the Burned Person.* Medical Examination Publishing, New York, pp. 136–146.

Sparrey, J. (1994) Aspects in the design and operation of shackle lines for the slaughter of poultry. M.Phil thesis, University of Newcastle upon Tyne, UK.

Sparrey, J.M. and Kettlewell, P.J. (1994) Shackling of poultry: is it a welfare problem? *World's Poultry Science Journal* 50, 167–176.

Sufka, K.J. and Hughes, R.A. (1990) Dose and temporal parameters of morphine-induced hyperalgesia in domestic fowl. *Physiology and Behaviour* 47, 385–387.

Sufka, K.J. and Hughes, R.A. (1992) Time-dependent codeine hypoalgesia and hyperalgesia in domestic fowl. *Pharmacology Biochemistry and Behaviour* 41, 349–353.

Torebjörk, H.E., Schmeiz, M. and Handwerker, H.O. (1996) Functional properties of human cutaneous nociceptors and their role in pain and hyperalgesia. In: Belmonte, C. and Cervero, F. (eds) *Neurobiology of Nociceptors*. Oxford University Press, Oxford, pp. 349–369.

Treede, R.D., Meyer, R.A., Raja, S.N. and Campbell, J.N. (1995) Evidence for two different heat transduction mechanisms in nociceptive primary afferents innervating monkey skin. *Journal of Physiology* 483, 747–758.

Wall, P.D. and Gutnick, M. (1974) Properties of afferent nerve impulses originating from a neuroma. *Nature* 248, 740–743.

Weddell, G. and Harpman, J.A. (1940) The neurohistological basis for the sensation of pain provoked from deep fascia, tendon and periosteum. *Journal of Neurology, Neurosurgery and Psychiatry* 3, 319–328.

Woolley, S.C. and Gentle, M.J. (1987) Physiological and behavioural responses in the hen (*Gallus domesticus*) to nociceptive stimulation. *Comparative Biochemistry and Physiology A*, 88, 27–31.

Yates, D.A.H. and Smith, M.A. (1995) Orthopaedic pain after trauma. In: Wall, P.D. (ed.) *Textbook of Pain*. Churchill Livingstone, Edinburgh, pp. 409–422.

Zimmermann, M. (1986) Behavioural investigations of pain in animals. In: Duncan, I.J.H. and Molony, V. (eds) *Assessing Pain in Farm Animals*. Commission of the European Communities, Luxembourg, pp. 30–35.

CHAPTER 17
Chicken cognition

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ABSTRACT

Information about the cognitive abilities of chickens should be considered when assessing hen welfare because it can help identify situations in which birds may suffer. Understanding bird cognition can also help in the development of improved methods of welfare assessment and the design of better housing systems. Research on chicken cognition is relatively sparse, but recent work has examined spatial ability, time perception and self-control, context sensitivity and inference, and social learning. Results from these studies are presented, together with an assessment of their welfare implications.

Studies of spatial cognition show that resource location is facilitated by an ability to form mental representations of objects that cannot be directly perceived. This suggests that chickens may have a concept of object permanence. One implication is that hens may miss resources that are absent and cannot be directly perceived. We cannot assume that 'out of sight is out of mind'. Spatial cognitive abilities develop with age and are strongly lateral. Chicks primarily use their left eye (right brain hemisphere) to encode spatial information. Full development of spatial ability depends on experience of a spatially diverse environment and on active interaction with objects in that environment. Older chickens can use both local and global cues, such as the sun's position, to orient. Work on spatial cognition can be applied to design housing systems that facilitate bird navigation and resource location. An important aspect of cognition is the question of whether animals live exclusively in the present, or whether they can think about the past or the future. The ability to represent the future provides the basis for a consideration of the consequences of an action. Recent work shows that chickens are able to estimate time and show self-control in foregoing a small reward in order to obtain a delayed larger reward. The ability of chickens to weigh up the consequences of their actions suggests that well-designed preference tests should continue to be an important tool in assessing hen welfare. We cannot dismiss hens' preferences on the basis that they do not have the cognitive ability to make an informed choice.

The behaviour of chickens often seems to be the product of rapid instinctive reaction rather than considered thought. Yet, chickens pay attention to complex combinations of environmental cues, and produce adaptive and finely tuned responses. Chickens do not always react in the same way to the same stimulus, their responses frequently depend on the context. Both male and female chickens are guided in their behaviour by the precise prevailing social environment and hens are able to draw rele-

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vant inferences from observation of the behaviour of other birds. In addition, chickens store and process information and then use this knowledge to make complex decisions about where to go, who to avoid, and how to maximize food intake.

They can also make use of the experience of conspecifics by acquiring information and new behaviours via social learning. Social learning is the acquisition of knowledge of skills by indirect observation or interaction with a conspecific and it provides an alternative to individual associative learning as a way of developing adaptive behaviour. Work on social learning can be applied to reduce the spread of unwanted behaviours such as feather pecking and cannibalism.

Further work on chicken cognition will inevitably provide new information about their capacity to know and to feel. This will have important ethical and legal implications.

INTRODUCTION

Chickens do not always react in the same way to the same stimulus; their responses may depend on the context. Both male and female chickens are guided in their behaviour by the precise prevailing social environment, and hens are able to draw relevant inferences from observation of the behaviour of other birds. In addition, chickens store and process information and then use this knowledge to make complex decisions about where to go, who to avoid, and how to maximize food intake. Resource location is facilitated by an ability to form mental representations of objects that cannot be directly perceived, and an ability to use both local and global cues, such as the sun's position, to orient. Chickens are able to estimate time and show self-control in foregoing a small reward in order to obtain a delayed larger reward. They can make use of the experience of conspecifics by acquiring information and new behaviours via social learning.

Knowledge of these cognitive abilities should be considered in an assessment of hen welfare. Not only may it help us to identify those situations in which animals may suffer (Nicol, 1996), it can also assist us to develop better methods of welfare assessment, design more effective housing systems and eliminate or control the spread of unwanted behaviour patterns.

The topics covered in this chapter are spatial cognition and object permanence, time perception and self-control, context sensitivity and inference, and social learning. The relevance of each of these for the welfare of the laying hen is discussed in the final section.

SPATIAL COGNITION AND OBJECT PERMANENCE

The question of how chickens perceive, understand and navigate through space is of growing relevance as increasing numbers of birds are kept in non-cage systems. In such large systems, resources are not always directly visible and birds may need to navigate towards remembered locations. Understanding how spatial abilities develop in chickens may allow the design of housing systems that facilitate accurate navigation.

Chicks of just a few days of age are able to locate a hidden object even in the absence of any orienting cues, acoustic, visual or olfactory, by moving towards the place where it was last observed (Freire and Nicol, 1999). Chicks also have the ability to take detours to reach highly valued social stimuli or companions (Regolin

*et al.,*1995). This suggests that chicks may possess a concept of object permanence, i.e. an appreciation that an object continues to exist even when not available to direct perception. It is interesting to consider what features are encoded by this mental representation. Chicks do not appear to be able to use their representation of an imprinted object to predict where it might reappear after it has moved at a constant speed behind a screen (Freire and Nicol, 1999). Perhaps their representation does not encode features such as movement, speed or direction. However, it is difficult to draw firm conclusions from negative results. The chicks in this study may have failed the movement prediction test because they were reared under artificial conditions that did not permit full cognitive development.

Spatial cognitive abilities develop with age and experience and, in chicks, are strongly lateral. Chicks are better at spatial learning and make more use of positional cues when using their left eye (right brain hemisphere) than their right eye (Tommasi and Vallortigara, 2001), and encoding of global spatial information appears to occur in the right hippocampus (Tommasi *et al*., 2003). Chicks that are temporarily able to use only their right eye are more likely to make use of local features such as the colour or shape of a visual cue (Vallortigara *et al*., 1996). During development, chicks show a sudden peak in movement out-of-sight of the mother at about day 11 of life and a similarly timed viewing bias towards the left eye (Vallortigara *et al*., 1997). Experience of the disappearance and reappearance of objects during this sensitive phase for the development of spatial memory is crucial. The specific role of experience of object occlusion at day 11 on subsequent performance on a range of spatial tests was examined by Freire *et al*. (2004). Chicks were individually imprinted on a ball stimulus, and then housed in pairs under different conditions from 8 to 12 days of age. Six pairs of chicks were able to walk around two opaque wooden barriers fitted in the pen, providing them with experience of disappearance and rediscovery of the ball and the other chick. The other 18 pairs of chicks were allocated to treatments that provided either two transparent barriers, one transparent and one opaque barrier, or no barriers within the pen. As under natural conditions, chicks showed a peak in moving out of sight of objects at day 11 of age. In subsequent tests, chicks with experience of object occlusion tended to show better retrieval of the hidden imprinting stimulus, and made fewer errors in a detour test. Providing passive experience of time spent out of sight of the imprinting stimulus by confining the chicks before testing resulted in no such improved performance in spatial tests. These results suggest that enrichment-induced improvement in spatial cognition is dependant on active interaction and experience of the environment gained during sensitive phases of development (Freire *et al*., 2004).

Despite these spatial abilities in chicks, Lipp *et al*. (2001) failed to show that chickens could locate food in the arms of an octagonal maze when consistent external-maze cues were provided. In other bird species, resource location over even very small distances is guided by a hierarchy of preference for global, landmark and local feature cues (Brodbeck, 1994; Chappell and Guilford, 1995). Thus, one possibility is that chickens failed the maze test because their preferred cues were not available.

In many bird species, the sun provides the preferred global cue that is used for resource location. To examine whether chickens could use information from the sun's position to locate food, Zimmerman *et al*. (2003) designed an experiment where the sun was the only consistent cue available. An eight-arm maze was

constructed and placed in an outdoor location, away from external landmark cues. Birds had to find food placed in just one arm of the maze in a compass direction that was consistent within individuals, but varied between subjects. Every day the maze was placed in a different part of a field, and was rotated. Food residue was placed in pots in all arms so that there were no consistent cues about food location available from visual or olfactory sources within the maze. When tested on sunny days, seven out of eight subjects reached the learning criterion, and consistently found food in the correct arm of the maze. Disrupting the chickens' perception of the earth's magnetic field did not disrupt their performance in this apparatus (P. Zimmerman *et al*., unpublished). This suggests that domestic fowl are able to use the global cue of the sun's position to navigate when other cues are not available, although it is not known whether they can compensate for the daily movement of the sun and use it as a compass, rather than as a beacon. Clock-shifting experiments would be required to test this.

TIME PERCEPTION AND SELF-CONTROL

An important aspect of cognition is the question of whether animals live exclusively in the present, or whether they can think about the past or the future. An animal that has no cognitive representation of the future will behave in a way that maximizes its immediate benefit. An animal that is able to consider the consequences of its actions may decide to forego immediate reward in order to maximize its benefit in the future.

This aspect of cognition has been studied in humans, rats and pigeons using a self-control paradigm. This requires an animal to choose between a less valuable reward available after a small time delay, and a more valuable reward after a longer delay. A subject that waits is said to show self-control. If both types of reward occur at the same frequency, an animal that shows self-control will obtain more food in total. The ability of birds to show self-control varies with species and with the exact experimental protocol employed (Logue, 1988; Stephens and Anderson, 2001). In order to succeed in a self-control task, a bird must be able to predict differences in waiting time, and be able to exhibit restraint.

The ability to estimate time intervals enables animals to predict the occurrence of events, but there has been only one study on the accuracy of time estimation in chickens. Taylor *et al*. (2002) showed that when domestic hens were given a signal indicating that pecking would be rewarded after a wait of 6 min, the majority of birds showed a peak in their maximum pecking response rate approximately 6–8 min after the signal. Thus, chickens are able to predict differences in waiting time, but are they able to restrain their impulse to obtain immediate food reward?

This possibility was recently investigated by Abeyesinghe *et al*. (2004) using both an operant chamber and a Y-maze. Sixteen naive hens were tested using both methods in a counterbalanced order. In the Y-maze, hens could choose to enter one compartment where a short (2 s) delay, indicated by a green light, was imposed before the bird obtained access to food for a short period (3 s), or a second compartment where a longer delay (6 s), indicated by a red light, was imposed before the bird obtained access to food for a longer period (7 s). In the operant chamber a similar procedure was followed. During experimental trials, pecks on one key initiated a short delay followed by a short period of access to

food reward, while pecks on the other key initiated a longer delay followed by a longer period of access. In the Y-maze, there was no overall preference for the chamber providing either immediate or delayed reward. In contrast, birds in the operant chamber exhibited a preference for immediate reward which became more pronounced as the experiment progressed.

The lack of response in the Y-maze may have been because birds genuinely had no preference, or they may have found it difficult to associate chambers with waiting times, and been unable to perform the discrimination required. Avoidance of the self-control option in the operant chamber suggested that birds could associate the operant keys with the onset of different waiting times using this method. The failure to show self-control in this case was therefore unlikely to be due to deficiencies in time estimation. It was therefore decided to perform a second operant experiment to determine whether hens would show self-control if the reward for waiting was substantially increased. When hens could choose between a short delay for a short period of food access and a longer delay for a much longer access (22 s compared with 6 s in the previous experiment) then the latter, self-control, option was selected in over 90% of trials. This indicates that chickens can show self-control for food.

CONTEXT SENSITIVITY AND INFERENCE

Chickens are often characterized as 'bird-brained' and their behaviour frequently seems to be the product of instinct rather than reason, of rapid reaction rather than considered reflection. Yet, chickens pay attention to complex combinations of environmental cues, and produce appropriate and finely tuned responses. Although this sensitivity may not count as deep thought (it may not involve concept formation), it certainly indicates that chickens are not simply reacting in just one stereotyped way to simple stimuli.

Good examples of context-specificity come from the alarm-calling and courtship behaviour of the male, and the maternal behaviour of female domestic fowl. Cockerels produce a characteristic vocal display when they encounter food, which attracts females to approach and accept food items. In playback experiments, hens responded selectively to male food calls by looking downwards, suggesting that the calls are functionally referential (Evans and Evans, 1999). Courtship vocalization is more frequent in the presence of a hen but is inhibited by the presence of another cockerel (Evans and Marler, 1994; Marler *et al*., 1986). However, males are even more sensitive to the nature of their audience, and are more likely to give courtship vocalizations if a female is unfamiliar, or if she is of the same strain and plumage-type as the male (Evans and Marler, 1992, 1994). Audience effects are also a feature of male alarm calling, although a broader range of audience characteristics elicit these types of calls. An audience of males, or females of any strain, will elicit alarm calling, although an audience comprising birds of a different species will not (Evans and Marler, 1991, 1992).

Hens attract their young to food with a complex display consisting of staccato food calls and pecking movements directed towards food items on the ground (Sherry, 1977). Hens give more intense and longer food calls in the presence of high-quality food items (Moffatt and Hogan, 1992) and this encourages chicks to peck more frequently at demonstrated items. Hens' display behaviour is also

sensitive to context and audience effects. The sight of young chicks inhibits maternal feeding and prolongs display (Sherry, 1977) and a hen will vocalize longer and give more food calls when chicks are visible, but physically separated from her, than when they are free to interact (Wauters *et al*., 1999).

The cognitive abilities of chickens are particularly highlighted by reports that hens can draw relevant inferences from observation of the behaviour of other birds. Hens respond according to their interpretation of available information. A fascinating example comes from an experiment which showed that hens assessed whether their chicks had acquired correct information about the edibility of food items (Nicol and Pope, 1996). Twelve broody hens were housed together with their chicks, except during feeding sessions that occurred four times daily. Hens were trained that feed of one colour was palatable, and feed of a different colour was unpalatable. Chicks from each brood were divided into two groups of equal size and fed separately. One group of chicks received one dish of palatable and one dish of unpalatable feed, coded using the same colours that the hen had been trained on. The other group of chicks received one dish of palatable and one dish of unpalatable feed, coded using the opposite colours from those used with the hen, ensuring that chicks in that group learned to feed on food of a colour that their mother had been trained to avoid. In subsequent test sessions, each broody hen observed the feeding behaviour of her two groups of chicks on alternate days, with colour and order counterbalanced across hens. Although there were no significant effects on broody hens' vocalization, other aspects of the maternal display were significantly increased when hens observed chicks that were making apparent errors. The intensity of the maternal display was increased, not in response to any chick disgust reaction, but in response to the hen's combined assessment of her chicks' feeding behaviour and her own information about food palatability.

Intriguingly, hens are also able to make relevant inferences about their social position within the flock by observation of agonistic interactions between flock mates. Hens will attack an unfamiliar hen if they have seen a flock mate defeat that stranger, but not if they have seen the stranger defeat the flock mate (Hogue *et al*., 1996).

SOCIAL LEARNING

Social learning, the acquisition of knowledge or skills by indirect observation or interaction with a conspecific, potentially provides a way of developing adaptive behaviour without the costs sometimes associated with individual learning. Social learning in chickens is functionally important in the development of food preferences, and also provides a mechanism by which hens can acquire novel behaviours.

Food Preferences

Newly hatched red jungle fowl chicks peck at food and non-food items alike, and have to learn which items are palatable and worthwhile to ingest (Hogan, 1984). The maternal behaviour of the hen assists chicks to discriminate food from non-food items, and can have a lasting influence on their food preferences. Gajdon

(2001) compared groups of hens and chicks, after hens had been trained to eat either red or green food in a test arena. The hens' food preferences were transferred to their chicks and were maintained by the chicks, even when they were later tested separately from hens. After the first week of life, chicks tend to move away from their mother and explore on their own. At this time, brood mates become potential, although probably less accomplished, food discoverers than the hen. The food preferences and foraging behaviour of chicks are, however, still significantly influenced by the behaviour of slightly older, pre-trained conspecifics (Gajdon *et al*., 2001).

McQuoid and Galef (1992, 1994) showed that jungle fowl chicks, 3 or 4 weeks of age, were attracted to particular marked feeding dishes or pen locations, 48 h after they had observed conspecifics feeding from the same type of dish or in the same location. When observers were unrewarded in their foraging behaviour during test sessions, only some birds pecked, and those that did peck did so for only a few seconds. However, when food rewards were introduced into test sessions, observers directed sustained pecking to sites where they had previously observed demonstrators feeding, even though equally rewarding, but non-demonstrated, sites were also available. This shows that, in slightly older birds, interactions between stimulus enhancement and individual associative learning are important.

Sherwin *et al*. (2002) examined the extent to which social learning influenced formation of food preferences and aversions in 9-week-old pullets. The aim of the first experiment was to determine whether observer pullets could learn to avoid pecking at a coloured food that elicited a 'disgust' reaction in a conspecific. A circular apparatus was designed that allowed eight observers at one time to see the feeding behaviour of a demonstrator placed in the centre of the apparatus. In total, 32 observers saw demonstrators exhibit 'disgust' reactions to unpalatable food, and 32 observers saw demonstrators eat normal food. Immediately after the observation sessions, observers were separated visually from each other and given two bowls of palatable coloured feed, with one of the colours matching that just demonstrated. During observation sessions, demonstrators given unpalatable feed performed much beak-wiping and head-shaking, behaviours seen rarely in demonstrators given standard feed. Despite such clear differences in demonstrator behaviour, observer pullets showed no avoidance of the coloured food that had elicited a disgust reaction in their demonstrators. This result contrasts with a study of day-old chicks by Johnston *et al*. (1998) which showed that chicks would avoid pecking at a bead if they had observed another chick exhibiting a disgust reaction. This may reflect an age-related change. Young chicks may be much more susceptible to social influence as the individual consequences of ingestion do not appear to control behaviour at this age.

In a second experiment using the same apparatus, observers saw demonstrators either not feeding, feeding on normal food, or feeding on 'highly palatable' feed (Sherwin *et al*., 2002). There were no treatment effects on total amount of food consumed by observers during the test. However, there was a positive correlation between the pecking rate of demonstrators and the proportion of feed of the demonstrated colour eaten by their respective observers. When this effect was examined more closely, it was apparent that there was an interaction with actual food colour. The effect of a highly palatable demonstration particularly induced birds to eat red food, which they otherwise tended to avoid. Red objects also elicit

elatively low levels of pecking by chicks and adult hens (Jones, 2002). The interaction between observational experience and food colour suggests that social learning in chickens might be important in overcoming unlearned aversions to particular colours that tend to signal unpalatability in nature (Guilford and Rowe, 1996).

New Skills

Adult laying hens acquire new operant key-pecking responses more effectively if they have previously observed a trained demonstrator (Nicol and Pope, 1992) and the social relationship between observer and demonstrator influences the extent to which information is transmitted (Nicol and Pope, 1994). In one study, flocks were randomly allocated to one of four treatments that differed in the type of demonstrator selected: either (i) the most dominant member of each group, (ii) the most subordinate member of each group, (iii) unfamiliar birds from a different population of laying hens, of unknown social rank, or (iv) no demonstrator. Although there were no significant differences in the performance characteristics of the different demonstrators, most correct key pecks were made by observers that had seen dominant demonstrators (Nicol and Pope, 1994).

One reason why dominant hens are more effective might be that they provide a more striking or noticeable presence during the performance of specific behaviours. Dominant birds might be bigger, adopt a taller body posture, or peck with greater force. However, this line of reasoning was not supported by a study that exposed hens to trained cockerels as demonstrators (Nicol and Pope, 1999). Despite the fact that the cockerels were larger, socially dominant to hens, and appeared to peck the key more forcefully, exposure to cockerels resulted in little social learning in hens, and all types of pecking were low when observers that had seen cockerels were tested in the response chamber. An alternative explanation is that dominance may be a correlate of some other indicator of quality. Dominant birds might receive more attention from conspecifics because of their success in some other domain, rather than because of their social position *per se*. The influence of foraging success as a direct cue was examined by Nicol and Pope (1999) in an experiment where prior foraging success of demonstrators was manipulated in their home pens. However, in subsequent key pecking tests no effects of manipulating prior foraging success of birds was found on their salience as demonstrators. This suggests that, although birds may pay selective attention to others that appear to be highly successful foragers (Sherwin *et al*., 2002), they do not appear to generalize the association and pay those same birds greater attention in a different foraging context.

It remains frustratingly unclear why dominant hens are more effective demonstrators than their subordinates. One factor that may be partially correlated with dominance in hens is aggressiveness. Although cockerels are socially dominant, they tend to engage in fewer agonistic interactions with hens than do other hens. In contrast, dominant hens may attract continuous attention from subordinates that are attempting to avoid situations that might result in threat, aggression or attack from dominants.

WELFARE IMPLICATIONS

Situations in Which Birds May Suffer

It is possible that laying hens do not 'miss' resources that are absent in their housing environment. A hen that is unable to perceive a suitable nest or dust-bathing substrate may have no mental representation of such a resource. If so, then 'out of sight is out of mind', and bird welfare may not be compromised.

It is difficult to examine this rather philosophical question experimentally but a variety of evidence suggests that out of sight may *not* be out of mind. First, birds deprived of either food or a litter substrate perform more searching behaviour in the absence of resource cues than non-deprived birds (Nicol and Guilford, 1991). This is not evidence for a mental representation of food or litter, as searching behaviour may be triggered by some non-perceived physiological change. However, it suggests that birds do not adapt fully to deprivation of resources. The possibility that they have mental representations of the missing resources is strengthened by findings that show chicks possess a mental representation of objects that cannot be directly perceived (Regolin *et al*., 1995). A recent study has also shown that birds may have a representation of food quality (Haskell *et al*., 2001). Chickens trained to run a maze to obtain food reacted with immediate frustration when the high-quality reward they expected was switched for a diet of lower quality. When birds were *expecting* low-quality diets they did not exhibit this frustration response, indicating that the behaviours seen were not a direct response to the diet.

Methods of Assessing Welfare

Preference tests are a very important method used to assess animal welfare. Yet an important criticism of them is that animals may not have the cognitive ability to weigh up longer term costs and benefits (Duncan, 1978). It is argued that animals' choices in preference tests may be impulsive rather than controlled or reflective. Although only a first step, experiments examining the ability of hens to wait for a reward are important. Hens clearly are able to weigh up the consequences of their actions and forgo a smaller reward for a larger one, if the larger one is sufficiently valuable (Abeyesinghe *et al*., 2004). Whether birds are able to weigh up the longer term consequences of their decisions in preference tests remains to be investigated.

Design of Housing or Husbandry Procedures

There has been rapid growth in knowledge about fundamental spatial cognitive abilities in chickens. This work now needs to be applied to the design of husbandry systems. If global lighting cues are preferred for navigation, even when other cues are present, this suggests that consideration should be given to optimizing lighting patterns in alternative systems to facilitate orderly bird movement and resource location.

Making use of new information about time estimation in birds, Taylor *et al*. (2002) suggested that the duration of specific events or husbandry procedures could be signalled, so that birds would know what to expect.

Elimination and Control of Unwanted Behaviour

Outbreaks of feather pecking are sporadic and unpredictable. However, once the behaviour arises within a flock it often spreads rapidly and social learning may play a part in its transmission within a flock (Nicol, 1995; Zeltner *et al*., 2000). Spatial clustering of similar environmental causes, and direct influences of changes in plumage condition that may occur once some birds begin to feather peck, are alternative explanations for transmission that also require further investigation.

Cloutier *et al*. (2002) examined the possibility that cannibalistic-type behaviour might be acquired via social learning. For practical and ethical reasons they devised an analogue of cannibalism which involved piercing a transparent membrane to access a pot of chicken blood. The proportion of pairs that pecked or pierced the membrane, the latency to peck or pierce the membrane, and the degree of membrane damage in the tests were all associated with observation of a pre-trained demonstrator.

Genetic selection and environmental improvement both offer potential routes to reduce feather pecking and cannibalism. However, the tendency to feather peck appears so ingrained in domestic fowl that it may not be possible to eliminate the behaviour entirely. If further work reveals an important role for social learning in transmission of such injurious behaviours, then consideration should be given to the use of visual partitions to reduce the chances of observational learning. Traditional management involves removing victims from the flock but, to slow the further spread of feather pecking, it may be more important to remove the birds performing the behaviour.

CONCLUSION

The study of the cognitive abilities of domestic fowl is in its early stages, but is a growing area of research. The poultry industry should be ready to make use of the findings to improve housing and management systems and bird welfare.

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REFERENCES

Abeyesinghe, S.M., Hartnell, S.J., Nicol, C.J. and Wathes, C.M. (2004) Can domestic fowl show self-control? *Animal Behaviour* (in press).

Brodbeck, D.R. (1994) Memory for spatial and local cues: a comparison of storing and non-storing species. *Animal Learning and Behaviour* 22, 119–133.

Chappell, J. and Guilford, T. (1995) Homing pigeons primarily use the sun compass rather than fixed directional visual cues in an open-field arena food-searching task. *Proceedings of the Royal Society of London, Series B, Biological Sciences* 260, 59–63.

Cloutier, S., Newberry, R.C., Honda, K. and Alldredge, J.R. (2002) Cannibalistic behaviour spread by social learning. *Animal Behaviour* 63, 1153–1162.

Duncan, I.J.H. (1978) The interpretation of preference tests in animal welfare. *Applied Animal Ethology* 4, 197–200.

Evans, C.S. and Evans, L. (1999) Chicken food calls are functionally referential. *Animal Behaviour* 58, 307–319.

Evans, C.S. and Marler, P. (1991) On the use of video images as social stimuli in birds: audience effects on alarm calling. *Animal Behaviour* 41, 1570–1572.

Evans, C.S. and Marler, P. (1992) Female appearance as a factor in the responsiveness of male chickens during anti-predator behaviour and courtship. *Animal Behaviour* 43, 137–145.

Evans, C.S. and Marler, P. (1994) Food calling and audience effects in male chickens *Gallus gallus*: their relationship to food availability, courtship and social facilitation. *Animal Behaviour* 47, 1159–1170.

Freire, R. and Nicol, C.J. (1999) Effect of experience of occlusion events on the domestic chick's strategy for locating a concealed imprinting object. *Animal Behaviour* 58, 593–599.

Freire, R., Cheng, H.-W. and Nicol, C.J. (2004) Development of spatial memory in occlusion-experienced domestic chicks. *Animal Behaviour* 67, 141–150.

Gajdon, G.K. (2001) Social modification of early foraging in domestic chickens. PhD thesis, University of Zurich.

Gajdon, G.K., Hungerbuhler, N. and Stauffacher, M. (2001) Social influence on early foraging of domestic chicks (*Gallus gallus*) in a near-to-nature procedure. *Ethology* 107, 913–937.

Guilford, T. and Rowe, C. (1996) Unpalatable evolutionary principles. *Nature* 382, 667–668.

Haskell, M.J., Vilarion, M., Savina, M., Atamna, J. and Picard, M. (2001) Do broiler chicks have a cognitive representation of food quality? Appetitive, behavioural and ingestive responses to a change in diet quality. *Applied Animal Behaviour Science* 72, 63–77.

Hogan, J.A. (1984) Pecking and feeding in chicks. *Learning and Motivation* 15, 360–376.

Hogue, M.-E., Beaugrand, J.P. and Lague, P.C. (1996) Coherent use of information by hens observing their former dominant defeating or being defeated by a stranger. *Behavioural Processes* 38, 241–252.

Johnston, A.N.B., Burne, T.H.J. and Rose, S.P.R. (1998) Observational learning in day-old chicks using a one-trial passive avoidance learning paradigm. *Animal Behaviour* 56, 1347–1353.

Jones, R.B. (2002) Role of comparative psychology in the development of effective environmental enrichment strategies to improve poultry welfare. *International Journal of Comparative Psychology* 15, 1–29.

Lipp, H.P., Pleskacheva, M.G., Gossweiler, H., Ricceri, L., Smirnova, A.A., Garin, N.N., Perepiolkina, O.P., Voronkov, D.N., Kuptsov, P.A. and Dell'Omo, G. (2001) A large outdoor radial maze for comparative studies in birds and mammals. *Neuroscience Review* 25, 83–99.

Logue, A.W. (1988) Research on self-control: an integrating framework. *Behavioural and Brain Sciences* 11, 665–709

Marler, P., Dufty, A. and Pickert, R. (1986) Vocal communication in the domestic chicken: is a sender sensitive to the presence and nature of a receiver? *Animal Behaviour* 34, 194–198.

McQuoid, L.M. and Galef, B.G. Jr (1992) Social influences on feeding site selection by Burmese fowl (*Gallus gallus*). *Journal of Comparative Psychology* 106, 137–141.

McQuoid, L.M. and Galef, B.G. Jr (1994) Effects of access to food during training on social learning by Burmese red junglefowl. *Animal Behaviour* 48, 737–739.

Moffatt, C.A. and Hogan, J.A. (1992) Ontogeny of chick responses to maternal food calls in the Burmese red junglefowl: a video analysis. *Animal Behaviour* 46, 13–22.

Nicol, C.J. (1995) The social transmission of information and behaviour. *Applied Animal Behaviour Science* 44, 79–98.

Nicol, C.J. (1996) Farm animal cognition. *Animal Science* 62, 375–391.

Nicol, C.J. and Guilford, T. (1991) Exploratory activity as a measure of motivation in deprived hens. *Animal Behaviour* 41, 333–341.

Nicol C.J. and Pope, S.J. (1992) Effects of social learning on the acquisition of discriminatory keypecking in hens. *Bulletin of the Psychonomic Society* 30, 293–296.

Nicol, C.J. and Pope, S.J. (1994) Social learning in small flocks of laying hens. *Animal Behaviour* 47, 1289–1296.

Nicol, C.J. and Pope, S.J. (1996) The maternal feeding display of domestic hens is sensitive to perceived chick error. *Animal Behaviour* 52, 767–774.

Nicol, C.J. and Pope, S.J. (1999) The effects of demonstrator social status and prior foraging success on social learning in domestic hens. *Animal Behaviour* 57, 163–171.

Regolin, L., Vallortigara, G. and Zanforlin, M. (1995) Detour behaviour in the domestic chick: searching for a disappearing prey or a disappearing social partner. *Animal Behaviour* 50, 203–211.

Sherry, D.F. (1977) Parental food-calling and the role of the young in the Burmese red junglefowl (*Gallus gallus spadiceus*). *Animal Behaviour* 25, 594–601.

Sherwin, C.M., Heyes, C.M. and Nicol, C.J. (2002) Social learning influences the preferences of domestic hens for novel food. *Animal Behaviour* 63, 933–942.

Stephens, D.W. and Anderson, D. (2001) The adaptive value of preference for immediacy: when shortsighted rules have farsighted consequences. *Behavioural Ecology* 12, 330–339.

Taylor, P.E., Haskell, M., Appleby, M.C. and Waran, N.K. (2002) Perception of time duration by domestic hens. *Applied Animal Behaviour Science* 76, 41–51.

Tommasi, L. and Vallortigara, G. (2001) Encoding of geometric and landmark information in the left and right hemispheres of the avian brain. *Behavioural Neuroscience* 115, 602–613.

Tommasi, L., Gagliardo, A., Andrew, R.J. and Vallortigara, G. (2003) Separate processing mechanisms for encoding of geometric and landmark information in the avian hippocampus. *European Journal of Neuroscience* 17, 1695–1702.

Vallortigara, G., Regolin, L., Bortolomiol, G. and Tommasi, L. (1996) Lateral asymmetries due to preferences in eye use during visual discrimination learning in chicks. *Behaviour and Brain Research* 74, 135–143.

Vallortigara, G., Andrew, R.J., Sertori, L. and Regolin, L. (1997) Sharply timed behavioural changes during the first 5 weeks of life in the domestic chick (*Gallus gallus*). *Bird Behaviour* 12, 29–40.

Wauters, A.M., Richard-Yris, M.A., Pierre, J.S., Lunel, C. and Richard, J.P. (1999) Influence of chicks and food quality on food calling in broody domestic hens. *Behaviour* 136, 919–933.

Zeltner, E., Klein, T. and Huber-Eicher, B. (2000) Is there social transmission of feather pecking in groups of laying hen chicks? *Animal Behaviour* 60, 211–216.

Zimmerman, P., Pope, S.J., Guilford, T. and Nicol, C.J. (2003) Navigational ability in the domestic fowl (*Gallus gallus domesticus*). *Applied Animal Behaviour Science* 80, 327–336.

CHAPTER 18
Social space for laying hens

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ABSTRACT

The spatial and social requirements of hens under commercial husbandry systems are not yet fully understood. Hens may require additional space to perform specific activities such as nesting or wing flapping or to minimize negative social interactions. In cage systems, the provision of physical environmental resources alone, without any additional space, may lead to physical and psychological restriction due to social competition. In colony systems it is likely that the greater potential freedom of movement, use of vertical space and group dynamics should provide ample opportunity for such activities, although there is a danger of an increase in agonistic interactions, where social strategies fail to cope with larger flock sizes. For these reasons, the reductions in stocking density being introduced in both cage and colony systems in Europe are likely to benefit hen welfare.

INTRODUCTION

The requirements of domestic hens for space and for an appropriate social environment are intrinsically linked. While it is possible to investigate spatial preferences of individual hens under experimental conditions, under commercial conditions, restrictions on individual space will be imposed as much by the presence of other hens as by the physical size of the enclosure. Space allowances for caged laying hens in the EU rose from 450 to 550 cm^2 per bird in 2003 (DEFRA, 2002). From 2012 this will increase to 600 cm^2 per bird of usable space in enriched cages and 750 cm^2 per bird including nest site (CEC, 1999). In colony systems, such as percheries, the size of the enclosure is larger, but group sizes increase proportionally so that overall ground space per bird is comparable to that in cages (DEFRA, 2002). With more extensive systems, for example free-range or certified schemes such as organic systems, stocking densities are lower still, although flock sizes can still number hundreds, if not thousands, of birds (Appleby *et al.*, 1992). In larger enclosures, although average spatial provision per bird is not much more than in cages, individual birds may nevertheless have more usable space than caged birds. This is as a result of increased use of the vertical dimension, as provided by perches or platforms, and due to the stochastic movements of the flock causing real or perceived transient increases in space within the enclosure

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(Keeling, 1995). These changes in stocking density have partly been driven by evidence from measures of well-being, including behavioural repertoire and environmental preferences (Appleby and Hughes, 1991; Appleby, 1993) and from effects on production (Hughes, 1975a), with falls in individual egg production (Adams and Craig, 1985; Appleby *et al*., 2002) and increased mortality as stocking density increases (Roush *et al*., 1984), although these effects may be offset on a purely economic basis by the increased flock productivity (Appleby *et al*., 2002; Wolffram *et al*., 2002).

SPATIAL REQUIREMENTS

Several approaches have been used to estimate the space that individual hens require. These include direct measures of the space each hen occupies (Dawkins and Hardie, 1989), measures of the value hens place on space (Lagedic and Faure, 1987; Nicol, 1986) and their response to increased space following periods of spatial restriction (Nicol, 1987a). Freeman (1983) and Hurnik and Lewis (1991) used the physical dimensions of the hen as a baseline for space requirements, though a more sophisticated approach is to measure the space hens use to perform different activities (Dawkins and Hardie, 1989). In this study, whilst activities such as standing required little more space than the physical size of the hen (475 cm^2 approx), other activities require considerably more room, such as ground scratching (850 cm^2), preening (1150 cm^2) and wing flapping (1876 cm^2). If these activities are valued (Cooper and Albentosa, 2003), then the performance of important activities may be impaired at high stocking densities.

In addition to the physical space required to perform specific activities, hens may also have a larger psychological space that may be infringed by the physical boundaries of the enclosure or the close proximity of flock mates. This can be seen in studies of the effect of spatial restriction on hens' behaviour (Nicol, 1987b; Keeling, 1994). Nicol (1987b) found that reducing the space allowance for pairs of hens from 1045 to 570 cm^2 per bird reduced the frequency of comfort activities such as body shaking and feather raising, whilst Keeling (1994) working with groups of three hens found that locomotion and ground pecking were significantly reduced as space was reduced from 5630 cm^2 to 600 cm^2 per bird. Under commercial conditions, increasing space per bird has a number of effects on behaviour, particularly an increase in locomotion, foraging, preening and dust bathing (Abrahamsson and Tauson, 1997; Carmichael *et al*., 1999; Freire *et al*., 1999; Appleby *et al*., 2002; Albentosa and Cooper, 2003). Furthermore, certain activities, including space-expensive comfort activities, are rarely observed in commercial cages even at low stocking densities (Freire *et al*., 1999; Appleby *et al*., 2002; Albentosa and Cooper, 2003). This low frequency suggests either that comfort activities are a low priority for caged birds, or that the hens do not perceive that there is sufficient room for adequate performance. To investigate this, Nicol (1987a) moved hens that had been singly housed, with either 847 cm^2 or 2310 cm^2 ground area available, to a 2310 cm^2 area enclosure. As with other studies, there was a lower incidence of comfort activities by hens with less personal space and these hens showed an apparent 'rebound' in wing stretching, feather raising, tail wagging, leg stretching and wing flapping on transfer to the larger enclosure. Whilst it is difficult to rule out the possibility that the hens were

responding to the novelty of increased space allowance (Nicol, 1987a), these results do suggest that certain activities are physically (and possibly psychologically) prevented by lack of space.

The hen's perception of space can also be investigated using preference tests or by asking the hens to work for additional space (Cooper and Albentosa, 2003). Several attempts have been made to investigate the cage size and height preferences of hens and the value they place upon them (e.g. Dawkins, 1977; Nicol, 1986). These studies have tended to use individual hens, as social factors such as gregariousness or antagonism may influence other hens' behaviour. Under experimental conditions, Hughes (1975b, 1977), Dawkins (1977, 1978, 1985) and Nicol (1986) have found that hens tend to prefer increased vertical and horizontal space. For example, Nicol (1986) found that individual hens prefer larger enclosures to smaller enclosures and Dawkins (1985) found that hens preferred higher cages to lower cages so long as the height differences were marked. In contrast, investigations of cage height preferences in groups of hens using the minimum cage heights laid down in law (DEFRA, 2002) of 38 cm versus 45 cm show no preference for the higher cages (Albentosa and Cooper, 2003). Whilst such findings suggest the hens do not perceive a difference between the two cage heights, it may be that any preferences are masked in group-housed hens if they place a higher value on personal space than cage height. At high stocking densities, small groups of familiar hens tend to distribute themselves evenly over the available space (Lindberg and Nicol, 1996a; Albentosa and Cooper, 2003) suggesting a behavioural priority to maximize individual space when space is limited.

A small number of studies have investigated the work that hens are prepared to carry out in order to increase environmental and/or social space (Faure, 1986; Lagedic and Faure, 1987). Faure (1986) trained groups of hens to peck a key to increase cage dimensions. He found that hens worked to maintain a trough width of only 100 mm per bird but had little inclination to increase this, suggesting that this would be enough trough space. They also found that groups of four hens would work to maintain cage size at 6000 cm^2 (1500 cm^2 per bird) but maintained a cage size of over 1600 cm^2 (400 cm^2 per bird) for only 25% of their time. This might suggest that for the majority of their time 400 cm^2 per bird was adequate but that hens periodically require larger areas to allow activities that require more space or simply chose to have a larger personal space. As commercial cages are manufactured with a fixed size, then if this additional space (and the activities it allows) is valued (even for a small proportion of time) this additional space should be provided in the cage design. Faure (1991) subsequently found that working for space was dependent on previous experience, because hens reared on floor pens with greater freedom of movement would work harder for additional cage space than hens that had been reared in cages. Therefore, further work is needed to investigate whether hens habituate to low personal space, whether the space available in proposed enriched cages is adequate, or alternatively, if hens require more personal space than is proposed in current legislation (CEC, 1999).

SOCIAL REQUIREMENTS

Relatively little is known about the social priorities of hens (i.e. the value placed on belonging to different group sizes or different group compositions) under

commercial husbandry systems. Jungle fowl, though social animals, tend to live in small stable groups (Dawkins, 1989; Collias and Collias, 1996). Feral hens adopt a similar social structure to their ancestors (McBride *et al.*, 1969; Wood-Gush and Duncan, 1976) and it is widely believed that there is a limit on the number of individuals that each hen is capable of recognizing of around 100 or so other hens (e.g. Guhl, 1958; Nicol *et al.*, 1999).

Investigations of group size preferences have been inconclusive (Dawkins, 1982). Hughes (1977) found that faced with choices of groups between zero and six unfamiliar resident hens, newly introduced hens preferred to join smaller groups. This was also found with familiar resident hens, although the effect was less pronounced. Lindberg and Nicol (1996b) reported that hens showed a strong preference for a group of five hens over a group of 120 hens in the same-sized space, but tended to prefer the larger group in a large space over the smaller group in a small space. They concluded that, whilst smaller group sizes may be preferable to hens, this would need to be combined with sufficient space. Therefore, interpreting preference tests for group size is difficult as, not surprisingly, test outcomes appear to be influenced by the context in which testing is carried out as well as the prior experience of the test birds (Hughes, 1977). Future studies should aim to provide hens with adequate experience of different group-size and group-structure choices on offer so that all aspects of being part of a certain group can be fairly tested. For example, it may be preferable to associate with familiar conspecifics in a small group in short-term tests, but for hens that regularly receive aggressive threats or attacks it may be preferable in the longer term to be part of a larger flock.

There is strong evidence that laying hens are able to discriminate between different individuals within their own social group (Bradshaw, 1991; Dawkins, 1995; D'Eath and Dawkins, 1996). When a preference between familiar and unfamiliar groups of hens is detected, hens associate with familiar rather than strange individuals or groups of hens (Hughes, 1977; Bradshaw, 1992). Furthermore, unfamiliar hens appear to act as an aversive stimulus to hens (Grigor *et al.*, 1995; Freire *et al.*, 1997). In small flocks such as those of caged laying hens, this means that hens have the opportunity to form stable hierarchies with minimal aggression, and hens may learn to tolerate the close proximity of others (Guhl, 1968; Meunier-Salaun and Faure, 1984; Keeling, 1995). In larger flocks this capacity to form stable hierarchies may be threatened by repeated exposure to unfamiliar hens. This is a concern both for large colony systems with several thousand individuals in each enclosure and for larger caged flocks (which may be one solution to the increased resource provision in enriched cages), with less opportunity to avoid aggressive individuals.

In larger flocks, it has been suggested that hens may adopt a number of alternative strategies to minimize aggressive encounters (Mench and Keeling, 2001). One solution is to move away from a social structure based on individual recognition to one based on generic signals of status such as physical features or behavioural signals. In the wild these badges or signals would have to be honest signals of status in order to survive over evolutionary time-scales, but in the artificial environment of the hen house, this may not be the case and short-term learnt rules or even heuristic rules of thumb may develop. For example, when kept in large groups, hens may switch from a social system based on remembered social hierarchies to a 'rule of thumb' system (Pagel and Dawkins, 1997), which might

involve a direct assessment of social status based, for example, on comparison of body and comb size (Guhl and Ortmann, 1953). Though there is good evidence of the use of badges of status in recognition and formation of relationships in experimental flocks (e.g. Dawkins, 1995; Cloutier *et al*., 1996), the degree to which these play a significant role in social behaviour in commercial conditions is unknown (Mench and Keeling, 2001), where hens are stocked closely together and where conventionally the whole flock is the same age and sex. Furthermore, with low light levels when using artificial lighting, signals such as comb colour may be less overt due to the effect of artificial lighting on the development of comb colour and interference with the hens' perception of colour (D'Eath and Stone, 1999).

Alternatively hens may adopt radically different social strategies in order to minimize agonistic interactions in larger flocks. This may be achieved by avoiding social interactions, adopting generally less threatening postures when faced with strangers, or the formation of subgroups within a flock, where hens would be surrounded by familiar flock mates and rarely be exposed to potentially aversive strangers. These is some evidence for these strategies with hens raised in larger flocks being generally less aggressive than those raised in smaller flocks (D'Eath and Keeling, 1998), some positional correlation between individuals within large flocks (Oden *et al*., 2000), or avoiding multiple social interactions by reduced movement within the flock (Freire *et al*., 2003). With the adoption of a number of alternative social strategies, the level of social stress within large flocks of laying hens is likely to be more variable than that experienced by individuals in small caged groups. Whether such factors would influence hens' choice of flock size is, however, yet to be determined.

SOCIAL SPACE

In group-housed hens, a major restriction on individual space is the presence of other hens, and individuals will compete to occupy the available space and exploit resources within their enclosure (Keeling, 1995). Under these conditions four types of social factors are likely to determine social and spacing behaviour. The first is *gregariousness*, whereby hens prefer to spend time in close proximity to each other, particularly if the flock mates are familiar. The second is *social facilitation* of behaviour, in its broadest sense, whereby the presence of others increases the likelihood of performing specific activities. An example of this would be local or stimulus enhancement, when feeding draws other hens' attention to food and causes crowding around food sources (Meunier-Salaun and Faure, 1984; Webster and Hurnik, 1994). The third factor is *competition*, where more than one individual attempts to exploit the same resource, which may lead to displacement from resources such as dust baths or nest sites (Abrahamsson and Tauson, 1997). Competition for resources in combination with limited opportunity to resolve disputes can lead to the fourth factor, *agonistic or aggressive interactions*, where hens may threaten or fight leading to injury, aversion and fear.

Gregariousness and social facilitation are likely to reduce inter-bird distances, while competition and agonistic interactions may increase inter-bird distance within the confines of their environment (Keeling, 1994). The effects of these factors will depend on a number of environmental factors, including the size of the enclosure, the number of hens in the flock, and the abundance of environmental

resources (Mench and Keeling, 2001). As a result of these complex interactions, the impact of apparently straightforward changes to the design of the hens' environment do not always have predictable effects on social structure and consequently hen welfare. For example, Al-Rawi and Craig (1975) found that increasing personal space from 412 to 824 cm^2 per bird in conventional cages increased aggressive interactions. This suggests an inhibitory effect of high stocking density on aggressive interactions in cages, though the effect of low cage height on expression and perception of signals of threats or submission will also be a contributing factor in the increased aggression at intermediate stocking densities.

With both the amount of physical space and the number and the nature of hens occupying that space as important factors in determining the quality/value of space, hens have a number of strategies available to them when choosing how to exploit the available environment (Cooper, 2004). The simplest distribution that hens might adopt is to randomly distribute over the available space. In this case neither the presence of other hens or the availability and location of resources have any effect on where hens choose to spend their time. In reality, for the reasons described above, it is unlikely that hens will pay no heed to their flock mates or resource position, so this type of distribution is unlikely. Nevertheless, a random distribution is a useful default from which to test whether hens adopt other types of distribution.

A second distribution would be one based on the hen's gregariousness, where hens are more likely to be found in close proximity than might be expected by chance. This could be investigated using measures based on proximity or average inter-bird distance (Keeling and Duncan, 1991; Lindberg and Nicol, 1996a). If inter-bird distances are smaller than would be expected by chance then this would suggest that they prefer to be close together. If hens were found to share locations more often than expected by a random distribution, then this would be evidence of clumping which may in turn indicate a tendency towards social cohesion due to gregariousness. These distributions would also be found if the hens' position was heavily dependent on the position of resources. For example, it may be that due to social enhancement of nest site selection, more hens are found in a nestbox than would be expected by chance (Appleby *et al.*, 1984). Discriminating between these two may be difficult, but again careful modelling and testing predictions, for example involving changing the number and/or location of resources, can address this.

Finally, hens may distribute so as to maximize personal space, in which case they would be expected to distribute evenly over the available space. For example in our own work involving enriched cages, one approach is to provide hens with a choice of two similar cages (Albentosa and Cooper, 2003). If hens randomly distribute across the two cages, then the frequency of each distribution across the two alternatives can be predicted from the binomial distribution. If the actual distribution deviates from this with more frequent observations of a biased distribution (i.e. most hens in one alternative, few hens in the other) then this might point to a gregarious distribution and would suggest that there is enough available space for hens to maintain acceptable social distances. On the other hand, if hens more frequently evenly distribute across the two alternatives (i.e. half the hens in one cage and half in the other) then this would suggest they are attempting to maximize personal space and consequently a cage of that size may not allow hens in that size of group to maintain acceptable social distances. An alternative explanation of this even

distribution would be that half the flock size is the preferred group size, although this can be further investigated by varying the relative size of the two enclosures and manipulating flock size.

These suggestions represent only four possible distributions. There may be more, and whilst each has been labelled with a causal basis, it is feasible that similar distributions can result from different combinations of causal factors. Evidence for even spacing has been found in small flocks of familiar hens in pens (McBride, 1970; Lindberg and Nicol, 1996a) but not in penned unfamiliar hens (Lindberg and Nicol, 1996a), which tend to clump and engage in aggressive interactions. In larger colonies at commercial stocking densities of 18 birds/m^2, hens did not evenly distribute but showed a wide variation in stocking density across the enclosure of between 9 and 41 birds/m^2 (Channing *et al.*, 2001), which may lead to overcrowding at these highest densities. In less restrictive enclosures, hens show clumping, even distributions, and quite wide, but random dispersal depending on ongoing activity (Keeling and Duncan, 1991; Collias and Collias, 1996). Furthermore, distributions may vary according to time of day and what the hens are doing, for example distribution when feeding, nesting or perching might differ considerably (Mench and Keeling, 2001). Nevertheless, these provide a framework for investigating social space in a variety of experimental and commercial situations.

SOCIAL SPACE IN COLONY SYSTEMS

Hens in cage systems and colony systems may have similar fundamental social spacing requirements but the degree to which these can be addressed differs between these two different types of environment. Whilst the majority of welfare research in laying hens has focused on cage systems, as these have been the dominant form of egg production, there has been an increasing interest in alternative systems in recent years. In principle, alternative systems provide additional resources such as litter, perches and nest sites that were not available in conventional wire cages, and greater individual space (FAWC, 1991, 1997) than is available in cages due to the use of vertical space and stochastic variation in inter-bird distances. Although concern has been expressed about the hen's capacity to recognize individuals, find a position within a social hierarchy, and consequently avoid repeated harmful aggressive interactions, studies have now shown that aggression levels are relatively low in these large flocks and hens appear to adopt a number of alternative strategies to avoid negative interactions. Aggressive behaviour is infrequent in large flocks compared to that reported in small to medium-sized flocks (Hughes *et al.*, 1997; Nicol *et al.*, 1999), possibly due to hens not recognizing flock mates as familiar or unfamiliar (Hughes *et al.*, 1997) or adopting alternative social strategies to reduce the chance of aversive social interactions (Mench and Keeling, 2001; Freire *et al.*, 2003).

Nevertheless, there may still be psychological denial of resources due to competition or avoidance of negative social interactions (Freire *et al.*, 2003). Consequences of these actions may include hens failing to exploit the environment fully, for example 'free-range' hens unwilling to leave the shed for fear of encountering unfamiliar or dominant individuals (Grigor *et al.*, 1995). Other socially mediated problems may also occur in large colony systems and these could lead to

production or welfare problems. Gregariousness and social facilitation may lead to overcrowding, as hens attempt to exploit similar resources at the same time (Channing *et al.*, 2001), whilst the hens' tendency to nest gregariously may lead to floor eggs, if many hens attempt to use the same nestbox or if eggs outside the nest act as a stimulus of nest-site choice (Appleby *et al.*, 1984). For these reasons, careful consideration of group dynamics, and the abundance and positioning of resources in the design and management of large colonies is necessary, in order to ensure that as many individuals as possible have sufficient space and access to resources to perform a full behavioural repertoire in non-cage systems.

SOCIAL SPACE IN CAGE SYSTEMS

In cage systems, hens face both the physical restriction of the size of the enclosure and the social restriction of having to share this with a number of other birds (Appleby and Hughes, 1991; Baxter, 1994; FAWC, 1997). Under these conditions, aggressive interactions are rare, as hens rapidly establish social hierarchies without the need to repeatedly fight. However, if aggressive interactions do occur, there is no opportunity to escape, so fights can escalate and rapidly lead to injury. The primary welfare concern with cages, however, has been that of behavioural restriction through lack of environmental resources such as nest sites, perches or foraging substrates and lack of space to exhibit locomotor and body maintenance activities (Appleby and Hughes, 1991). Providing additional resources such as enclosed nest sites, raised perches and substrates to allow foraging and dust bathing activities in furnished cages may reduce behavioural restriction (Freire *et al.*, 1999; Appleby *et al.*, 2002) but may lead to increased competition for these resources. Consequently, legislation to include these resources in cage environments is generally accompanied by increases in cage dimensions (CEC, 1999; DEFRA, 2002). Some concern has been expressed over providing more physical space, as aggressive interactions may increase if hens have sufficient space to fight, although thus far no studies of increasing social space in furnished cages have reported any increases in aggression.

The question remains as to what is an acceptable amount of space per bird. Individual space has increased to 550 cm^2 per bird over recent years and will increase to 750 cm^2 per bird in enriched cages in 2012 in Europe. This is likely to benefit birds by providing more opportunity to control personal space. In addition, movements within the flock may open up temporary larger areas that may allow the expression of more space-expensive activities such as foraging, dust bathing or wing flapping. As yet it is not clear if this increased space will actually allow adequate expression of such activities. It may be that even though the hens have sufficient physical space to perform the activities, they do not perceive the enclosure as large enough, and as a consequence their spatial requirements may be far larger that is physically necessary to demonstrate the activity. This question requires further work, particularly as cages are typically built to a single dimension and if this extra space is truly highly valued then considerably larger cages may be required to allow hens the space they need than has up until now been considered in legislation.

REFERENCES

Abrahamsson, P. and Tauson R. (1997) Effects of group size on performance, health and birds' use of facilities in furnished cages for laying hens. *Acta Agriculturae Scandinavica, Section A, Animal Science* 47, 254–260.

Adams, A.W. and Craig, J.V. (1985) Effect of crowding and cage shape on productivity and profitability of caged layers: a survey. *Poultry Science* 64, 238–242.

Albentosa, M.J. and Cooper, J.J. (2003) Cage height preferences of groups of hens housed in furnished cages. *British Poultry Science* 44, S5–S6.

Al-Rawi, B. and Craig, J.V. (1975) Agonistic behaviour of caged chickens related to group size and area per bird. *Applied Animal Ethology* 2, 69–80.

Appleby, M.C. (1993) Should cages for laying hens be banned or modified? *Animal Welfare* 2, 67–80.

Appleby, M.C. and Hughes, B.O. (1991) Welfare of laying hens in cages and alternative systems: environmental, physical and behavioural aspects. *World's Poultry Science Journal* 47, 109–128.

Appleby, M.C., McRae, H.E., Duncan, I.J.H. and Bisazza, A. (1984) Choice of social conditions by laying hens. *British Poultry Science* 25, 111–117.

Appleby, M.C., Hughes, B.O. and Elson, A. (1992) *Poultry Production Systems: Behaviour, Management and Welfare*. CAB International, Wallingford, UK.

Appleby, M.C., Walker, A.W., Nicol, C.J., Freire, R., Hughes, B.O. and Elson, H.A. (2002) Development of furnished cages for laying hens. *British Poultry Science* 43, 489–500.

Baxter, M.R. (1994) The welfare problems of laying hens in battery cages. *Veterinary Record* 134, 614–619.

Bradshaw, R.H. (1991) Discrimination of group members by laying hens *Gallus domesticus*. *Behavioural Processes* 24, 143–151.

Bradshaw, R.H. (1992) Conspecific discrimination and social preference in the laying hen. *Applied Animal Behaviour Science* 33, 69–75.

Carmichael, N.L., Walker, A.W. and Hughes, B.O. (1999) Laying hens in large flocks in a perchery system: influence of stocking density on location use of resources and behaviour. *British Poultry Science* 40, 165–176.

CEC (Commission of the European Communities) (1999) Council Directive 99/74/EC: laying down minimum standards for the protection of laying hens. *Official Journal of the European Communities* (L 203/53) 19 July.

Channing, C.E., Hughes, B.O. and Walker, A.W. (2001) Spatial distribution and behaviour of laying hens housed in an alternative system. *Applied Animal Behaviour Science* 72, 335–345.

Cloutier, S., Beaugrand, J.P. and Lague, P.C. (1996) The role of individual differences and patterns of resolution in the formation of dominance orders in domestic hen triads. *Behavioural Processes* 38, 227–239.

Collias, N.E. and Collias, E.C. (1996) Social organisation of red junglefowl, *Gallus gallus*, population related to evolutionary theory. *Animal Behaviour* 51, 1337–1354.

Cooper, J.J. (2004) Consumer demand under commercial husbandry conditions: practical advice on measuring behavioural priorities in captive animals. *Animal Welfare* S13, 47–56.

Cooper, J.J. and Albentosa, M.J. (2003) Behavioural needs in the domestic hen. *Avian and Poultry Science Reviews* 14, 127–149.

Dawkins, M.S. (1977) Do hens suffer in battery cages? Environmental preferences and welfare. *Animal Behaviour* 25, 1034–1046.

Dawkins, M.S. (1978) Welfare and the structure of a battery cage: size and cage floor preferences in domestic hens. *British Veterinary Journal* 134, 469–475.
Dawkins, M.S. (1982) Elusive concept of group size in domestic hens. *Applied Animal Ethology* 2, 69–80; *Applied Animal Ethology* 8, 365–375.
Dawkins, M.S. (1985) Cage height preference and use in battery kept hens. *Veterinary Record* 116, 345–347.
Dawkins, M.S. (1989) Time budgets in red junglefowl as a baseline for the assessment of welfare in domestic fowl. *Applied Animal Behaviour Science* 24, 77–80.
Dawkins, M.S. (1995) How do hens view other hens? The use of lateral and binocular vision in social recognition. *Behaviour* 132, 591–606.
Dawkins, M.S. and Hardie, S. (1989) Space needs of laying hens. *British Poultry Science* 30, 413–416.
D'Eath, R.B. and Dawkins, M.S. (1996) Laying hens do not discriminate between video images of conspecifics. *Animal Behaviour* 52, 903–912.
D'Eath, R.B. and Keeling, L.J. (1998) Social discrimination by hens in small flocks: implications for social organisation. In: Veissier, I. and Boissy, A. (eds) *Proceedings of the 32nd Congress of the International Society for Applied Ethology*, 21–25 July 1998, Clermont-Ferrand, France. INRA, France.
D'Eath, R.B. and Stone, R.J. (1999) Chickens use visual cues in social discrimination: an experiment with coloured lighting. *Applied Animal Behaviour Science* 62, 233–242.
DEFRA (Department of Environment, Food and Rural Affairs) (2002) *Code of Recommendations for the Welfare of Livestock: Laying Hens*. DEFRA Publication, London, UK.
Faure, J.M. (1986) Operant determination of the cage and feeder size preferences of the laying hen. *Applied Animal Behaviour Science* 15, 325–336.
Faure, J.M. (1991) Rearing conditions and needs for space and litter in laying hens. *Applied Animal Behaviour Science* 31, 111–117.
FAWC (Farm Animal Welfare Council) (1991) *Report on the Welfare of Laying Hens in Colony Systems*. FAWC, Tolworth, UK.
FAWC (Farm Animal Welfare Council) (1997) *Report on the Welfare of Laying Hens*. FAWC, Tolworth, UK.
Freeman, B.M. (1983) Floor space allowances for the caged domestic fowl. *Veterinary Record* 112, 562–563.
Freire, R., Appleby, M.C. and Hughes, B.O. (1997) Assessment of pre-laying motivation in the domestic hen using social interaction. *Animal Behaviour* 54, 313–319.
Freire, R., Walker, A. and Nicol, C.J. (1999) The relationship between trough height, feather cover and behaviour of laying hens in modified cages. A*pplied Animal Behaviour Science* 63, 55–64.
Freire, R., Wilkins, L.J., Short, F. and Nicol, C.J. (2003) Behaviour and welfare of individual hens in a non-cage system. *British Poultry Science* 44, 22–29.
Grigor, P.N., Hughes, B.O. and Appleby, M.C. (1995) Social inhibition of movement in domestic hens. *Animal Behaviour* 49, 1381–1388.
Guhl, A.M. (1958) The development of social organisation in the domestic fowl. *Animal Behaviour* 6, 92–111.
Guhl, A.M. (1968) Social inertia and social stability in chickens. *Animal Behaviour* 16, 219–232.
Guhl, A.M. and Ortman, L.L. (1953) Visual patterns in the recognition of individuals among chickens. *Condor* 55, 287–298.
Hughes, B.O. (1975a) The concept of an optimum stocking density and its selection

for egg production. In: Freeman, B.M. and Boorman, K.N. (eds) *Economic Factors Affecting Egg Production*. British Poultry Science Ltd., Edinburgh, pp. 271–298.

Hughes, B.O. (1975b) Spatial preference in the domestic hen. *British Veterinary Journal* 131, 560–564.

Hughes, B.O. (1977) Selection of group size by individual laying hens. *British Poultry Science* 18, 9–18.

Hughes, B.O., Carmichael, N.L., Walker, A.W. and Grigor, P.N. (1997) Low incidence of aggression in large flocks of laying hens. *Applied Animal Behaviour Science* 54, 215–234.

Hurnik, J.F. and Lewis, N.J. (1991) Body-surface area, a reference for space allowance in confinement. *Poultry Science* 70, 412–415.

Keeling, L.J. (1994) Inter-bird distances and behavioural priorities in laying hens: the effect of spatial restriction. *Applied Animal Behaviour Science* 39, 131–140.

Keeling, L.J. (1995) Spacing behaviour and an ethological approach to assessing optimum space allocations for groups of laying hens. *Applied Animal Behaviour Science* 44, 171–186.

Keeling, L.J. and Duncan, I.J.H. (1991) Social spacing in domestic fowl under semi-natural conditions: the effect of behavioural activity and activity transitions. *Applied Animal Behaviour Science* 32, 205–217.

Lagedic, H. and Faure, J.M. (1987) Preferences of domestic hens for cage height and floor types as determined by operant conditioning. *Applied Animal Behaviour Science* 19, 147–155.

Lindberg, A.C. and Nicol, C.J. (1996a) Effects of social and environmental familiarity on group preferences and spacing behaviour in laying hens. *Applied Animal Behaviour Science* 49, 109–123.

Lindberg, A.C. and Nicol, C.J. (1996b) Space and density effects on group size preferences in laying hens. *British Poultry Science* 37, 709–721.

McBride, G. (1970) The social control of behaviour in fowls. In: Freeman, B.M and Gordon, R.F. (eds) *Aspects of Poultry Behaviour*. WPSA, Edinburgh, pp. 3–13.

McBride, G., Parer, I.P. and Foenander, F. (1969) The social organisation and behaviour of the feral domestic fowl. *Animal Behaviour Monographs* 2, 125–181.

Mench, J. and Keeling L.J. (2001) The social behaviour of domestic birds. In: Keeling, L.J. and Gonyou, H.W. (eds) *Social Behaviour in Farm Animals.* CAB International, Wallingford, UK, pp. 177–209.

Meunier-Salaun, M.C. and Faure, J.M. (1984) On the feeding behaviour of the laying hen. *Applied Animal Behaviour Science* 13, 129–141.

Nicol, C.J. (1986) Non-exclusive spatial preference in the laying hen. *Applied Animal Behaviour Science* 15, 337–350.

Nicol, C.J. (1987a) Behavioural responses of laying hens following a period of spatial restriction. *Animal Behaviour* 35, 1709–1719.

Nicol, C.J. (1987b) Effect of cage height and area on the behaviour of hens housed in battery cages. *British Poultry Science* 28, 327–335.

Nicol, C.J., Gregory, N.G., Knowles, T.G., Parkman, I.D. and Wilkins, L.J. (1999) Differential effects of increased stocking density, mediated by increased flock size, on feather pecking and aggression in laying hens. *Applied Animal Behaviour Science* 65, 137–152.

Oden, K., Vestergaard, K.S. and Algers, B. (2000) Space use and agonistic behaviour in relation to sex composition in large flocks of laying hens. *Applied Animal Behaviour Science* 67, 307–320.

Pagel, M. and Dawkins, M.S. (1997) Peck orders and group size in laying hens: 'futures contracts' for non-aggression. *Behavioural Processes* 40, 13–25.

Roush, W.B., Mashaly, M.M. and Graves, H.B. (1984) Effect of increased bird population in a fixed cage area on production and economic responses of single comb white leghorn laying hens. *Poultry Science* 63, 45–48.

Webster, A.B. and Hurnik, J.F. (1994) Synchronization of behavior among laying hens in battery cages. *Applied Animal Behaviour Science* 40, 153–165.

Wolffram, R., Simons, J., Giebel, A. and Bongaerts, R. (2002) Impacts of stricter legal standards in the EU for keeping laying hens in battery cages. *World's Poultry Science Journal* 58, 365–370.

Wood-Gush, D.G.M. and Duncan, I.J.H. (1976) Some behavioural observations on domestic fowl in the wild. *Applied Animal Ethology* 2, 255–260.

CHAPTER 19
Nesting, perching and dustbathing

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ABSTRACT

Jungle fowl have many behavioural adaptations that fit them to their environment, and laying hens show almost all of them. But only a few of these behaviour patterns actually require a physical resource to perform them. Thus there is little discussion on the importance of being able to lie down or stand up, or even preen, in laying hens, but there is discussion about nesting behaviour, perching and dustbathing. From 2012 all systems for laying hens will be required to provide a nestbox, a perch and a litter area. This chapter reviews the evidence for that decision, and highlights those areas where research is still needed if this requirement is to be satisfied in a practical way in commercial housing conditions, while at the same time upholding the intention of the law to improve hen welfare.

The functions of nesting, perching and dustbathing under natural conditions would be to increase the number of offspring surviving to the next generation. Initially it was argued that because the eggs laid by hens kept commercially are not fertile, are removed every day, and the hens are protected from predators or extremes of cold, then they do not need to perform these behaviour patterns in captivity. However, there is a large body of scientific research demonstrating the importance to the hen of being able to perform these behaviour patterns. In general it has been shown that given the choice, hens choose to use the resource when it is available, will show an operant response, and will work to get access to the resource at certain times of the day or after being deprived of the resource for some time. When the resource is not available, the appetitive part of the behaviour is often prolonged and hens may show signs thought to be indicative of frustration. For nest-building and dustbathing, sham behaviours are seen, i.e. the hen goes through the motions of the behaviour despite the lack of the necessary resource. In combination, this evidence clearly indicates that hens are highly motivated to perform nesting, perching and dustbathing and that the decision to require the provision of these resources is justified.

It is, however, necessary to provide the resource in such a way and in such a form that it does indeed improve the welfare of hens. Simply adding the resource without due consideration to the hen's ability to use it or the additional welfare problems it may cause is not in keeping with the intention of EC Directive 1999/74/EU. It is in this area that more work is needed if practical solutions are to be reached within the timeframe available. There is a considerable amount of work on nestbox design to make nestboxes that are both attractive to hens as well as feasible to construct and include in

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loose or cage housing systems. There is even a reliable body of work on perch form, design and placing within housing systems. The remaining most critical problem area seems to be in relation to the requirement for provisions to be provided for dustbathing. In loose housing systems this is not usually an issue, since a part of the floor is converted to litter and the total available area is large. However it is a topic of debate in cage systems, since it has been clearly demonstrated that many hens do not use the litter area when it is provided. Given the experimental work showing the importance of litter-directed behaviours and the clear link between access to litter and feather pecking, the onus is on the farmer to provide the litter in an appropriate way so that hens use it and so experience the welfare benefits of its presence.

INTRODUCTION

The EC Directive (1999/74/EU) states that systems for the housing of hens that have reached laying maturity must be equipped with a nest, perches and litter. This chapter reviews the evidence that lies behind the EC decision to include these resources, but focuses on research that has been published since 1996, when the Scientific Veterinary Committee's report on which this Directive was based was published (EC, 1996). The chapter also, where appropriate, comments on where more research is needed on nesting, perching and dustbathing if this Directive is to be implemented successfully.

The three behaviour patterns in the title of this chapter are all shown by jungle fowl, the ancestor of the modern laying hen. They are behaviours that have been under selection pressure, since they have clear implications for survival and evolutionary fitness. Typically, animals have a high level of motivation to perform such behaviours and show indicators of frustration if they are prevented from performing them. Many other behaviour patterns shown by hens have fitness consequences but are never questioned or even discussed in terms of legislation. It is obvious that one must provide hens with food and water and so there is no need to discuss the importance of feeding and drinking behaviour. Behaviours such as preening, stretching and body shaking are not directed at a physical object and can, within reason, be performed anywhere at any time, so are not discussed in terms of legislation either. Nesting, perching and dustbathing are, however, exceptions. Research has shown that hens are motivated to perform these behaviours, but they require resources; a nestbox, a perch and litter, respectively, in order to perform them. On the other hand, they are not essential for survival within a modern farming system and so have not traditionally been included in all housing systems. This dilemma has led to these three behaviour patterns being the focus of attention in recent years, and that is why they have their own chapter in this book.

The word 'motivation' is used to describe internal processes that arouse and direct behaviour. An animal's motivation is a consequence of the interaction between internal factors underlying the tendency to perform that behaviour (e.g. ovulation is linked to nesting) and external factors that tend to trigger the performance of that behaviour (e.g. the sight of new litter material is linked to dustbathing). Since internal and external factors vary, so the motivation to perform a particular behaviour varies over time, between individuals and in different environments. Scientists have developed many methods to study motivation, and the most common of these used by poultry researchers to investigate the motivation for nesting, perching and dustbathing are preference tests, operant techniques and

thwarting of the motivated behaviour. As suggested by the name, *preference tests* are when the hen itself is allowed to choose the situation it prefers. *Operant techniques* refer to a situation in which the hen has to do something (operate a lever or push open a door) in order to be able to perform the behaviour. The advantage of operant techniques is that they give a quantitative measure of motivation, whereas preference tests give only a relative measure e.g. that A is preferred over B. The assumption is that hens will choose what is important to them and the more important it is, the more effort they will put into attaining it. In *thwarting studies* the hen is prevented from performing a behaviour. If the hen is highly motivated to perform the behaviour that has been thwarted then it is likely to show behaviour patterns indicative of frustration and, if the thwarting persists, the hen may even develop abnormal behaviour patterns. All these techniques have been used to varying extents in studies of nesting, perching and dustbathing motivation and will be referred to in the following sections.

NESTING BEHAVIOUR

Nesting behaviour includes the behaviour patterns that lead to the selection of a protected nest site and building a suitable nest. Under natural conditions, nesting behaviour increases the chances of eggs hatching successfully. In fact, eggs laid outside a nest in the wild are unlikely to contribute to the biological fitness of the mother hen. Since nest sites are a limited resource, one can say with some degree of certainty that a hen would always have to show nesting behaviour if she was going to hatch any chicks. Behaviour patterns that are always necessary tend to be more fixed and less flexible than behaviour patterns that are required only occasionally. Thus, although the time taken to find the nest site and build the nest may vary depending on the environment, hens will always show some nesting behaviour. It is this fact that seems to lie behind the many results demonstrating that hens, even highly selected modern hybrids, are motivated to show nesting behaviour. Brooding behaviour has been selected against during the process of improving egg production, but there has not been any conscious selection against nesting behaviour.

Several experiments revealed that hens were motivated to lay their egg in a nestbox (Appleby and McRae, 1986; Duncan and Kite, 1989) and later work has confirmed this (Cooper and Appleby, 1995, 1996a). When a nestbox is not provided then hens spend longer in the nest-searching phase of nesting behaviour (Cooper and Appleby, 1995; Freire *et al.*, 1996). They also increase the performance of the gakel-call, which is an indicator of frustration, when nesting behaviour is thwarted by blocking access to the nest (Zimmerman *et al.*, 2000). The motivation to get access to a secluded nest site to lay an egg has been measured by how hard a hen will push through a small gap and has been estimated to be higher even than the motivation to feed following 4-h food deprivation (Cooper and Appleby, 2003). This study also showed that motivation increases closer to the time of actual egg laying. Thus, in conclusion, there was and still is convincing evidence that it is important for hens to be able to lay their egg in a suitable nest site.

Of practical help to the provision of a nestbox under commercial conditions has been the suggestion that performance of nest building is more important to a hen than the actual construction of a nest (Hughes *et al.*, 1989). As a

consequence, the view developed that one only needed to provide the simplest version of a nest that satisfies a hen and that work to assess the essential features of a nest would be worthwhile. Work along these lines has been carried out by several researchers to tease apart the aspects of loose material, a hollow, enclosure and the like, that are used by hens to identify a nest (Duncan and Kite, 1989; Reed and Nicol, 1992). While there are some limits on, for example, how small the AstroTurf can be in a nest and still be attractive (Wall *et al*., 2002), it does seem that relatively simple designs of nestbox are sufficient to stimulate nesting behaviour.

However, even when attractive nestboxes are provided, some hens still lay their eggs outside the nests (Sherwin and Nicol, 1993). The question remains as to whether or not this is a welfare problem for the hen, and the answer lies in why the hens do not use the nests. If the hen is motivated to lay in a nest, but cannot find what to her is an appropriate site so, as a last resort, lays in an inappropriate place, then it probably is a welfare problem. To this hen, there is no nest. However, if she chooses to lay her egg outside the nestbox provided because she perceives the place she selects as the most appropriate, or if she lays outside the nest because she is not motivated to lay her egg in a protected nest site, then it probably is not a welfare problem. To this hen, there is a nest. There is some evidence to support both arguments. Certainly there is a large individual variation in preferences for nest design (Sherwin and Nicol, 1993). But there is also evidence that some hens are genuinely less motivated to gain access to nestboxes (Cooper and Appleby, 1996b). This may reflect relaxed selection pressure on nest site selection.

Also of concern is that although aggression is generally low in loose housing systems, it is high outside nestboxes (Oden *et al*., 2002), which may imply that despite knowledge of nest design, they are not positioned optimally in the building. It has been clearly demonstrated that hens reared without perches are less able to find and use raised nestboxes (Appleby *et al*., 1988) and this has been confirmed in epidemiological studies on commercial farms (Gunnarsson *et al*., 1999). However, these recent results on aggression may support the long-held view that some hens lay on the floor because they are not able to compete effectively for nests, even if they can reach them. Observations on commercial farms show a large variation in the number of floor eggs (0.7–18.4%, Abrahamsson and Tauson (1998); 0.9–11.5%, van Horne (1996)), demonstrating that at least some farms do succeed in having very low levels of floor eggs.

In conclusion, the relatively small amount of new work in this area since the EC (1996) report may be an indicator that scientists are in agreement about the importance of nesting behaviour.

PERCHING

Perching is most noticeable in the early evening, when hens go up on to a perch. This night-time roosting behaviour is triggered under natural conditions by decreasing daylight (Kent *et al*., 1997) and so could be facilitated under commercial conditions by gradually dimming the lighting. Presumably perching at night has the functional benefits of reducing risk of predation from ground predators, although in cold climates it may have the additional benefits of conserving body warmth.

Certainly hens prefer to use the highest perches (Newberry *et al.*, 2001) and seem to be rather conservative in their choice of perching locations, returning to similar locations on consecutive evenings (Oden *et al.*, 2000). Hens also use perches during the day, although to a lesser extent than at night-time, and they seem to use them mainly for resting and preening. Access to perches may also contribute to reduced fearfulness in hens in general (Scott *et al.*, 1998)

Using techniques similar to those used to investigate nesting motivation, it has been demonstrated that hens are motivated to roost at night-time (Olsson and Keeling, 2002a) and that they show signs of frustration when access to perches is blocked (Olsson and Keeling, 2000). There has been little, if any, work on individual differences in perch preferences, but one can question whether perches at, or close to, floor level are really perceived as perches by hens, in the light of the fact that egg laying while standing on perches has been observed in cages (Appleby *et al.*, 1998).

Under natural conditions young chicks learn to perch from their mother, but even without the mother hen, chicks usually learn to use perches if they are available during the first weeks of life. Nevertheless, the ability to learn to move in three-dimensional space decreases with increasing age (Appleby *et al.*, 1988). This apparent lack of ability in hens reared without perches may also contribute to hens not finding food and water when moved to an aviary system from floor rearing. It has even been demonstrated that early access to perches significantly decreases flock mortality levels attributable to cloacal cannibalism (Gunnarsson *et al.*, 1999). In summary, there seem to be many beneficial behavioural effects of providing hens under commercial conditions with the opportunity to perform perching behaviour.

Although it is difficult to separate out skill at perching from motivation to perch, a series of experiments has been done to test the jumping skills of hens by getting them to jump between perches of different heights or distances. In brief, the average laying hen has problems jumping further than 1 m, and finds going up easier than coming down (Scott *et al.*, 1999; Green *et al.*, this volume, part V, Poster 5). This can be particularly important, considering the large proportion of hens that possess broken bones at slaughter or, perhaps worse still, healed breaks that are presumably due to crashing in the system, as reported elsewhere in this book. Thus the position of perches in relation to one another is important in loose housing systems, although it is important also in cages if manure build-up on the floor is to be avoided (Abrahamsson and Tauson, 1993).

Another aspect to be taken into consideration when building perches is the material from which the perches are made and the dimensions of the perch. There has been considerable work in this area (Tauson and Abrahamsson, 1996; Lambe and Scott, 1998) and hens in general seem to avoid small-diameter, completely round perches, preferring oval-shaped perches that are perhaps easier to grip.

The work on motivation to perch strengthens the argument that perching is an important behaviour for hens and so supports the inclusion of perches in housing systems for hens. The recent work on how hens move between perches also helps to position perches more appropriately in the system. It can be concluded that there is still strong evidence for the provision of perches.

DUSTBATHING

Dustbathing seems to function to remove excess lipids and ectoparasites. In combination with preening it helps keep the plumage in good condition, which is of course important for survival in the wild (van Liere, 1992). In some studies hens have been shown to work for access to litter to dustbathe (Matthews *et al.*, 1998; Widowski and Duncan, 2000), but not in all studies, implying that it may be sensitive to experimental design or that hens are working for litter in which they may either dustbathe or use for pecking and scratching in, depending on their motivational state at that time (see discussion in Widowski and Duncan, 2000). The prevention of dustbathing has been shown to lead to an increase in vocalization (Zimmerman *et al.*, 2000), suggesting that hens are frustrated when access to a dust bath is blocked, and it was shown that dust-deprived hens orient towards dustbathing hens even when access is blocked (Olsson *et al.*, 2002a).

When hens are deprived for longer periods of time, they show sham dustbathing behaviour, and an experiment which allowed sham dustbathing or not found no difference in the later motivation of the hens to dustbathe in litter, suggesting that sham dustbathing is not a substitute for dustbathing in litter (Olsson *et al.*, 2002b). Although it has been discussed whether pecking the feed while sham dustbathing is a satisfactory substitute for hens (Lindberg and Nicol, 1997), other studies have suggested that deprivation of dustbathing is stressful (Vestergaard *et al.*, 1997; Campo and Munzo, 2001). In combination, the evidence for the importance of dustbathing is still strong, but it is difficult to separate motivation for dustbathing from motivation to access litter for other activities such as ground pecking and scratching. The importance of access to litter for foraging behaviour in reducing feather pecking is well documented (see Rodenburg and Koene, this volume, Chapter 21).

Providing litter for hens, whether for dustbathing or foraging does, however, present practical problems. Litter contributes to dust in the poultry house and if not managed effectively it can become wet and caked and so is an unsuitable substrate for dustbathing (Oden *et al.*, 2002). When it is in good, friable condition, the litter area is well used, sometimes giving very high stocking densities at the peak dustbathing time in the middle of the day (Oden *et al.*, 2002). On the other hand, in furnished cages, the dust baths seem to be less attractive and frequently remain unused by hens (Lindberg and Nicol, 1997). There is no evidence that this is due to social competition for the dust bath, as hens may sham dustbathe on the floor even when the dust bath is empty (Olsson and Keeling, 2002b). This finding begs the question of whether it is the design that is unsatisfactory or whether, quite simply, hens are not used to dustbathing in litter, since hens to be housed in furnished cages are usually reared in cages without litter. More work is clearly needed in this area since there seems to be a trend in some recent designs of furnished cages to provide a pecking and scratching area, as required in the EC Directive, but make little or no attempt to provide for dustbathing behaviour. Also of importance in furnished cages is the fact that the dust bath is often closed when the hens are first placed in the cages as pullets. Later it is open each day only after peak egg laying time i.e. in the afternoons, even if most dustbathing occurs around midday. Although such practical advice may decrease the number of eggs laid in the dust bath, and so facilitate appropriate use of the nestbox, it may reduce the use of the litter area and have negative consequences for dustbathing behaviour.

Given the success in identifying a simplified type of nestbox, which seems to satisfy the nesting requirements of laying hens, there is a need to determine how minimalist a dust bath can be while still satisfying the dustbathing motivation of hens. Dustbathing behaviour consists of many different components and only some of these may be necessary for the hen to get satisfactory feedback from the performance of the behaviour.

COMBINING RESOURCES FOR FLOCKS OF HENS

The sections above rely mainly on information from experimental studies to study one particular behaviour pattern, often with individual hens. In practice, though, nestboxes, perches and litter are all provided in a system, and hens are almost always kept in groups. Decisions on where, when and how individual hens perform nesting, perching and dustbathing behaviour occur therefore in much more complicated commercial environments than in experimental situations, and interactions should be expected. For example, hens tend to roost at the highest location. In practice this may be in or on the edge of a nestbox, if that is higher than the perch that is available to them, or if the highest level perches are occupied by other hens (Abrahamsson and Tauson, 1997; Oden *et al*., 2002). Another example is when a hen selects the area intended as the dust bath as the most appropriate location to lay its egg, rather than the nestbox.

As well as differences in how individual hens use resources compared to how they are intended to be used, there are diurnal rhythms in egg laying, dustbathing and perching. Synchronization is when hens perform the behaviour at the same time of day and may be attributable to this diurnal rhythm, which acts on each hen individually, or to social influences on the timing of behaviour. Social facilitation is a specific type of social influence, which results in hens performing more of the behaviour in the presence of others performing the same behaviour. Both will result in hens tending to use the same resources at the same time. This emphasizes the need to provide sufficient resources to satisfy hens at certain times, even if these same resources remain unused for much of the remaining time. There is little systematic research on separating out synchronization effects from social facilitation effects on nesting, perching and dustbathing behaviour, although recent research does not support the commonly held view that dustbathing behaviour is socially facilitated (Olsson *et al*., 2002b; Lundberg and Keeling, 2003) even if it is clearly synchronized.

If a behaviour is synchronized or socially facilitated, or both, there may be an even greater motivation to perform that behaviour when hens are in groups compared to experimental studies with individual hens. In short, while it may be frustrating for a hen to be able to see a resource, but not be able to use it, it may be even more frustrating to see another hen performing a particular behaviour and not be able to join it. Research in this area would help with the decisions on actual space allocations of nestboxes, perches and litter, given that in this chapter it is argued that there is still strong evidence that they should be provided.

In addition to more experimental studies, studies under commercial conditions are also important in relation to the performance of different behaviour patterns. There has been a welcome trend in recent years towards carrying out surveys or simple behavioural observations on a large number of commercial farms

(Gunnarsson *et al*., 1999; Hüber-Eicher and Audigé, 1999; Pötzsch *et al*., 2001; Oden *et al*., 2002) and to analysing the results using behavioural and epidemiological techniques. Such work helps to understand how small differences in the design of resources like nestboxes, perches and dust baths can lead to large differences in nesting, perching and dustbathing behaviour.

REARING EFFECTS

The EC Directive refers to adult hens, but how hens are reared has an important impact on their later behaviour. It has already been mentioned that early access to perches affects later spatial ability (Gunnarsson *et al*., 2000). It also influences a hen's perception of what is an appropriate resource, as shown for litter by Petherick *et al*. (1995), although experience as an adult may supersede earlier preferences (Nicol *et al*., 2001). Thus, although there is the possibility of 'correcting' mistakes made during rearing, hens should probably be prepared much more thoroughly for the resources they will encounter as adults. It may be that this early investment in the behaviour of young hens saves time and money when dealing with laying-hen behaviour later in life.

SUMMARY

The evidence for the importance of nesting and perching behaviour in hens has been strengthened by recent findings and so there is support for provision of a nestbox and perch for hens in the EC Directive. The evidence for the importance of dustbathing is still strong, but recent work suggests that more research is required to fully understand the motivation of hens to show this behaviour pattern. However, in combination with the importance of litter for foraging, there is still an argument for providing suitable litter material to hens.

REFERENCES

Abrahamsson, P. and Tauson, R. (1993) Effect of perches at different positions in conventional cages for laying hens of two different strains. *Acta Agriculturae Scandinavica, Section A, Animal Science* 43, 228–235.

Abrahamsson, P. and Tauson, R. (1997) Effects of group size on performance, health and birds' use of facilities in furnished cages for laying hens. *Acta Agriculturae Scandinavica, Section A, Animal Science* 47, 254–260.

Abrahamsson, P. and Tauson, R. (1998) Performance and egg quality of laying hens in an aviary system. *Journal of Applied Poultry Science* 7, 225–232.

Appleby, M.C. and McRae, H.E. (1986) The individual nest box as a superstimulus for domestic hens. *Applied Animal Behaviour Science* 15, 169–176.

Appleby, M.C., Duncan, I.J.H. and McRae, H.E. (1988) Perching and floor laying by domestic hens: experimental results and their commercial implications. *British Poultry Science* 29, 351–357.

Appleby, M.C., Hughes, B.O., McDonald, M. and Cordiner, L.S. (1998) Factors affecting the use of perches in cages by laying hens. *British Poultry Science* 39, 186–190.

Campo, J.L. and Munzo, I. (2001) Relationship between dust bathing activity and stress- or fear-related responses in white, tinted, and brown egg breeds of chickens. *Archiv für Geflugelkunde* 65, 88–91.

Cooper, J.J. and Appleby, M.C. (1995) Nesting behaviour of hens: effects of experience on motivation. *Applied Animal Behaviour Science* 42, 283–295.

Cooper, J.J. and Appleby, M.C. (1996a) Demand for nest boxes in laying hens. *Behavioural Processes* 36, 171–182.

Cooper, J.J. and Appleby, M.C. (1996b) Individual variation in prelaying behaviour and the incidence of floor eggs. *British Poultry Science* 37, 245–253.

Cooper, J.J. and Appleby, M.C. (2003) The value of environmental resources to domestic hens: a comparison of the work-rate for food and for nests as a function of time. *Animal Welfare* 12, 39–52.

Duncan, I.J.H. and Kite, V.G. (1989) Nest site selection and nest-building behaviour in domestic fowl. *Animal Behaviour* 37, 215–231.

EC (European Commission) (1996) *Report of the Scientific Veterinary Committee, Animal Welfare Section on the Welfare of Laying Hens*. Brussels, 30 October 1996.

Freire, R., Appleby, M.C. and Hughes, B.O. (1996) Effects of nest quality and other cues for exploration on pre-laying behaviour. *Applied Animal Behaviour Science* 48, 37–46.

Gunnarsson, S., Keeling, L.J. and Svedberg, J. (1999) Effect of rearing factors on the prevalence of floor eggs, cloacal cannibalism and feather pecking in commercial flocks of loose housed laying hens. *British Poultry Science* 40, 12–18.

Gunnarsson, S., Yngvesson, J., Keeling, L.J. and Forkman, B. (2000) Rearing without early access to perches impairs the spatial skills of laying hens. *Applied Animal Behaviour Science* 67, 217–228.

Hüber-Eicher, B. and Audigé, L. (1999) Analysis of risk factors for the occurrence of feather pecking in laying hen growers. *British Poultry Science* 40, 599–604.

Hughes, B.O., Duncan, I.J.H. and Brown, F. (1989) The performance of nest building by domestic hens: is it more important than the construction of a nest? *Animal Behaviour* 37, 210–214.

Kent, J.P., McElligott, A.G. and Budgey, H. (1997) Ground-roosting in domestic fowl (*Gallus gallus domesticus*) in the Gambia: the anticipation of night. *Behavioural Processes* 39, 271–278.

Lambe, N.R. and Scott, G. (1998) Perching behaviour and references for different perch designs among laying hens. *Animal Welfare* 7, 203–216.

Lindberg, A.C. and Nicol, C.J. (1997) Dustbathing in modified battery cages: is sham dustbathing an adequate substitute? *Applied Animal Behaviour Science* 55, 113–128.

Lundberg, A. and Keeling, L.J. (2003) Social effects on dustbathing behaviour in laying hens: using video images to investigate effect of rank. *Applied Animal Behaviour Science* 81, 43–57.

Matthews, L.R., Walker, J., Foster, T.M. and Temple, W. (1998) Influence of reward magnitude on elasticity of demand for dustbathing in hens. In: Veissier, I. and Boissy, A. (eds) *Proceedings of the 32rd Congress of the International Society of Applied Ethology, Clermont Ferrand, France*. INRA, France, p. 86.

Newberry, R.C., Estevez, I. and Keeling, L.J. (2001) Group size and perching behaviour in young domestic fowl. *Applied Animal Behaviour Science* 73, 117–129.

Nicol, C.J., Lindberg, A.C., Phillips, A.J., Pope, S.J., Wilkens, L.J. and Green, L.E. (2001) Influence of prior exposure to wood shavings on feather pecking, dustbathing and foraging in adult laying hens. *Applied Animal Behaviour Science* 73, 141–155.

Oden, K., Vestergaard, K.S. and Algers, B. (2000) Space use and agonistic behaviour in relation to sex composition in large flocks of laying hens. *Applied Animal Behaviour Science* 67, 307–320.

Oden, K., Keeling, L.J. and Algers, B. (2002) Behaviour of layers in two types of aviary system on 25 commercial farms in Sweden. *British Poultry Science* 43, 169–181.

Olsson, I.A.S. and Keeling, L.J. (2000) Night-time roosting in laying hens and the effect of thwarting access to perches. *Applied Animal Behaviour Science* 68, 243–256.

Olsson, I.A.S. and Keeling, L.J. (2002a) The push-door for measuring motivation in hens: laying hens are motivated to perch at night. *Animal Welfare* 11, 11–19.

Olsson, I.A.S. and Keeling, L.J. (2002b) No effect of social competition on sham dustbathing in furnished cages for laying hens. *Acta Agriculturae Scandinavica, Section A, Animal Science* 52, 253–256.

Olsson, I.A.S., Duncan, I.J.H., Keeling, L.J. and Widowski, T.M. (2002a) How important is social facilitation for dustbathing in laying hens? *Applied Animal Behaviour Science* 79, 285–297.

Olsson, I.A.S., Keeling, L.J. and Duncan, I.J.H. (2002b) Why do hens sham dustbathe when they have litter? *Applied Animal Behaviour Science* 76, 53–64.

Petherick, J.C., Seawright, E., Waddington, D., Duncan, I.J.H. and Murphy, L.B. (1995) The role of perception in the causation of dustbathing behaviour in domestic fowl. *Animal Behaviour* 49, 1521–1530.

Pötzsch, C.J., Lewis, K., Nicol, C.J. and Green, L.E. (2001) A cross-sectional study of the prevalence of vent pecking in laying hens in alternative systems and its associations with feather pecking, management and disease. *Applied Animal Behaviour Science* 74, 259–272.

Reed, H.J. and Nicol, C.J. (1992) Effects of nest linings, pecking strips and partitioning on nest use and behaviour in modified battery cages. *British Poultry Science* 33, 719–727.

Scott, G.B., Conell, B.J. and Lambe, N.R. (1998) The fear levels after transport of hens from cages and a free-range system. *Poultry Science* 77, 62–66.

Scott, G.B., Hughes, B.O., Lambe, N.R. and Waddington, D. (1999) Ability of laying hens to jump between perches: individual variation and the effects of perch separation and motivation on behaviour. *British Poultry Science* 40, 177–184.

Sherwin, C.M. and Nicol, C.J. (1993) A descriptive account of the pre-laying behaviour of hens housed individually in modified cages with nests. *Applied Animal Behaviour Science* 38, 49–60.

Tauson, R. and Abrahamsson, P. (1996) Foot and keel bone disorders in laying hens. *Acta Agriculturae Scandinavica, Section A, Animal Science* 46, 239–246.

van Horne, P.L.M. (1996) Production and economic results of commercial flocks with white layers in aviary systems and battery cages. *British Poultry Science* 37, 255–261.

van Liere, D.W. (1992) The significance of fowls' bathing in dust. *Animal Welfare* 1, 187–202.

Vestergaard, K.S., Skadhauge, E. and Lawson, L.G. (1997) The stress of not being able to perform dustbathing in laying hens. *Physiology and Behaviour* 62, 413–419.

Widowski, T.M. and Duncan, I.J.H. (2000) Working for a dustbath: are hens increasing pleasure rather than reducing suffering? *Applied Animal Behaviour Science* 68, 39–53.

Wall, H., Tauson, R. and Elwinger, K. (2002) Effect of nest design, passages and hybrid on use of nest and production performance of layers in furnished cages. *Poultry Science* 81, 333–339.

Zimmerman, P.H., Koene, P. and van Hoof, J. (2000) Thwarting of behaviour in different contexts and the gakel-call in the laying hen. *Applied Animal Behaviour Science* 69, 255–264.

CHAPTER 20
Environmental enrichment: the need for practical strategies to improve poultry welfare

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ABSTRACT

The banning of traditional battery cages for laying hens in the European Community from 2012 largely reflects consumers' wishes for their food to be produced with greater respect for animal welfare. However, farmers also need to make a living and alternative housing systems can generate their own welfare and production problems. Therefore, to ensure sustainability of European agriculture, we must identify practical ways of minimizing major behavioural problems, like fear and feather pecking. Environmental enrichment may help in this respect. However, the birds ignore many so-called enrichment devices and others exert undesirable effects. Rather than relying on human preconceptions to guide the development of enrichment, we should establish the birds' preferences.

Enrichment procedures must satisfy critical requirements; these include practicality, sustained interest, promotion of desirable behaviours and reduction of harmful ones. This chapter provides an overview of recent findings.

- Televised stimuli attracted chickens; their regular presentation reduced fear, and effective images incorporated movement, brightness, colour, and moderate complexity. Although we cannot introduce televisions into poultry houses, projecting images on to the walls might be practicable.
- Farmers reported that playing the radio reduced aggression, improved the birds' health and increased productivity; this strategy also enriches the farmers' environment.
- The presence of a familiar odorant reduced chicks' fear of novel places, birds and food; indicating that olfactory therapy might minimize certain behavioural problems.
- Ultraviolet light might be used as enrichment because it reduced injurious pecking in turkeys and the basal corticosterone level in chicks; this merits further investigation.
- Providing chickens with string promoted foraging, sustained lengthy interest, and reduced feather pecking and feather damage in the laboratory and at a commercial farm.

Clearly, extraneous stimulation is important to chickens. Although environmental enrichment should not be regarded as a panacea for welfare problems, the provision of appropriate visual, auditory, olfactory and tactile enrichment is likely to improve their quality of life.

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INTRODUCTION

Gathering information and engaging in exploratory and foraging behaviour are integral parts of the chicken's behavioural development and welfare (Rogers, 1995; Newberry, 1999; Jones, 2002). For example, hens housed in pens with sufficient resources still explored an adjacent empty area (Nicol and Guildford, 1991). Rearing chickens in impoverished environments leads to apathy, boredom, fear, and abnormal, often harmful behaviours (Jones, 2001, 2002). Despite this, they are often housed in barren or inappropriate environments that provide little to occupy their interest. On a positive note, this offers ample opportunities for improving welfare via relatively simple changes to the environment. Environmental enrichment could help. Concisely, 'environmental enrichment' is often defined as a means of increasing the complexity and, hence, the stimulus value of the animals' physical environment. This strategy is now widely used to develop stimulating environments for zoo and laboratory animals, thereby enhancing animal–environment interactions. In essence, enrichment is intended to expand the repertoire of desirable behaviours, reduce the occurrence of harmful ones, sustain the animals' interest and enable them to cope with challenges in a 'more normal fashion' (Chamove, 1989; Jones, 1996, 2002). Our studies focused mainly on determining the effects of enrichment on two major welfare insults, namely fear and feather pecking.

Although domestication has increased docility, chickens are still frightened of people (often perceived as predators) or sudden changes in the environment (Jones, 1996). Panic-related injuries, pain, distress, reduced growth, impaired reproductive performance and poorer product quality can all accompany the sudden, intense or prolonged elicitation of fear (Jones, 1996; Hemsworth and Coleman, 1998). Fearful birds are also less able to interact successfully with their physical and social environment.

Traditional battery cages for laying hens will be banned in the European Community from 2012. However, feather pecking (FP), which occurs when a bird pecks at and pulls out another's feathers (Blokhuis, 1986), hampers the adoption of putative welfare-friendly alternative housing systems because it is much more difficult to control when the birds are kept in large flocks. As well as its economic cost, severe FP damages the birds' welfare: (i) by causing pain and fear; (ii) by increasing susceptibility to injury via decreased feather cover; and (iii) by leading to cannibalism and the painful death of target birds (Craig and Muir, 1998; Jones and Hocking, 1999). Current remedial measures (beak trimming; low light) have their associated welfare problems (pain, eye abnormalities, visual impoverishment). Additionally, although it is distinct from FP, aggressive pecking is also emerging as a significant problem in some breeds (King, 2001).

The development of acceptable, practicable methods of minimizing fear, FP, cannibalism and aggression is imperative from the birds', the farmers' and the public's viewpoints. Genetic selection may offer a rapid means of promoting welfare-friendly traits and minimizing harmful ones (see Craig and Muir, 1998; Jones and Hocking, 1999; Faure *et al*., 2003) but the present chapter focuses on environmental manipulations.

Providing perches, dust baths and nestboxes in 'enriched cages' for laying hens may satisfy some of the birds' behavioural needs, e.g. for roosting, a suitable substrate for dustbathing, and partial seclusion during oviposition. For the present purposes though, I focus mainly on enrichment in its more traditional sense, i.e.

as a means of increasing animal–environment interaction through added complexity and stimulation. This can be achieved by giving the birds conspicuous objects that they can manipulate, although pictures, video images, diverse feeds, sounds and smells have also been used (Mench, 1994; Bubier, 1996; Jones, 1996, 2001; Jones and Roper, 1997). Such enrichment can reduce fearfulness, FP, aggression, and depopulation trauma as well as improving poultry health and productivity (see Jones, 2001, 2002). Diverse inorganic and organic stimuli, including drawings, silver paper, buttons, tubing, shoelaces, flowers, toys, balls, bells, concrete blocks, tin plates, mealworms, seeds, grass and commercially available 'toys', have been used. Beneficial effects were reported in several studies. For example, the provision of various objects or coloured feeds reduced underlying fearfulness and neophobia in domestic chicks (Jones and Waddington, 1992; Jones, 2001); the incorporation of organic and inorganic material in floor pens reduced aggression (and perhaps frustration) in laying hens (Bubier, 1996); providing straw or wood shavings increased foraging and reduced FP in laying hen chicks (Huber-Eicher and Wechsler, 1997; Huber-Eicher and Sebo, 2001); and introducing straw bales increased activity in broilers (Kells *et al*., 2001) and reduced aggression in broiler breeders (King, 2001). However, the results have not always been consistent; the birds often ignored many of the so-called enrichment stimuli, and some enrichment devices actually exerted undesirable effects (see Jones, 2002). In the latter context, providing operant feeders, plastic rods and a commercially available 'enrichment device' (Agri-Toy) led to increased aggressive pecking among laying hens housed in floor pens (Lindberg and Nicol, 1994). Furthermore, whereas enriching the physical environment reduced fear in broiler chickens, combining such enrichment with regular handling, which is also a putative form of enrichment (Jones, 2002), had the opposite effect (Nicol, 1992). These findings emphasize the need for caution in our definition and application of environmental enrichment.

Some of the above inconsistencies may have arisen because the stimuli had been chosen according to human preconceptions rather than a critical consideration of what a chicken might find enriching. The design of poultry enrichment devices requires critical thought (Mench, 1994; Jones, 1996) but, while it is easy to assert that sentient animals should not be kept in barren enclosures, it is less easy to decide precisely what to do for the best (Webster, 1994). Furthermore, the lack of baseline ethograms and time budgets for feral counterparts hampers the assessment of enrichment procedures. However, surrogate measures, such as approach/avoidance, duration of contact, and patterns of response to putative enrichment stimuli as well as the catalogue of associated effects provide valuable information.

Given the mounting evidence that chicks of layer and broiler strains as well as adult laying hens find enrichment stimuli attractive (McKenzie *et al*., 1998; Jones and Carmichael, 1999a; Newberry, 1999; Clarke and Jones, 2000a), I discuss chickens' responses to selected visual, auditory, olfactory and tactile stimuli and their implications for the development of practicable and effective environmental enrichment.

VIDEO PLAYBACK MAY GUIDE ENVIRONMENTAL ENRICHMENT

Chickens show appropriate responses to televised images of predators and of feeding, dustbathing or threatening conspecifics (see Clarke and Jones, 2000a).

Chicks were increasingly attracted to videos of screensavers (images that delay the degradation of computer screens) when these were repeatedly presented at one end of their home cage (Jones *et al*., 1998). They also preferred a familiar screensaver to a blank screen and a moderately novel one to the familiar image in a novel two-choice runway apparatus. Clearly, chicks can remember video images and moderate novelty is attractive. Similarly, when a 'Fish' video was presented to laying hens on 20 consecutive days they spent much of the time looking out of the cage at the screen (Clarke and Jones, 2000b). Although interest waned gradually after 8 days, it was fully restored when an unfamiliar video ('Doodles') was shown on day 21. Additionally, regular exposure to video stimulation reduced chicks' fear of novel places (see Clarke and Jones, 2000a). The fear-reducing effects of video playback and its ability to sustain interest suggested that it might be a form of enrichment, so we determined the specific attributes influencing attractiveness. Chicks preferred bright to dull (38 versus 18 lux), moving to still, and coloured to greytone versions of the Fish screensaver; they also preferred 'Fish' to a simple bouncing square ('Square'), and a complex cartoon ('The Simpsons') to the 'Fish' video (Clarke and Jones, 2000a). Repeated exposure elicited increasing interest regardless of content, and complex images elicited the strongest preferences (Clarke and Jones, 2000a). We should now determine whether interest could be sustained for long periods if a video remained on screen permanently while showing a range of changing images.

The present video images were always shown outside the birds' cages, and adult hens readily looked through small spy-holes drilled in the opaque wall of their home cage in order to view unfamiliar areas or birds (McKenzie *et al*., 1998). Furthermore, laboratory primates will readily view and interact with external videos (Platt and Novak, 1997). Collectively, these reports suggest that we should enrich the environment outside as well as inside an animal's cage.

PLAYING THE RADIO MAY BE BENEFICIAL

The often-cited concept that music helps chickens to thrive is difficult to test experimentally because of the diffuse nature of sound. Therefore, in collaboration with the National Farmers Union, we surveyed more than 100 UK poultry farmers to determine the incidence and perceived benefits of playing the radio. Of the farmers surveyed, 46% reported that they routinely played music; of these 96%, 52%, 20% and 16% claimed that it made the hens calmer, less aggressive, healthier and more productive, respectively (Jones and Rayner, 1999). We must exercise some caution here because, to date, there has been no independent verification of the farmers' reports. However, the welfare and economic benefits described above could be explained in various ways:

- Listening to the radio might calm the farmers and thereby improve their care of the animals and, as a consequence, the man–animal relationship.
- Farmers who play music may be more concerned about their animals' welfare and consequently adopt better practice, thereby improving production.
- The additional and varied sounds may partially satisfy the birds' need for stimulation.
- Playing the radio may help the birds to learn that unfamiliar sounds are not

necessarily dangerous. This could, in turn, reduce the likelihood of panic when the birds hear unfamiliar or loud noises, such as someone sneezing, shouting, dropping a bucket or slamming a door.

Regardless of the underpinning mechanism(s), playing the radio is probably the easiest, most practicable way of enriching the environment for both the chickens and the farmers.

FAMILIAR ODOURS REASSURE CHICKENS IN UNFAMILIAR SITUATIONS

Chickens have a reasonably well-developed olfactory system and they respond appropriately to olfactory cues, e.g. they use odours as 'learning' cues, they avoid odours of predators or blood, and they are reluctant to accept familiar food if it has a novel smell (see Jones and Roper, 1997). Chickens are likely to encounter various novel, and hence fear-eliciting, stimuli (e.g. new places, objects, food) during their lifetime, and many of them are hesitant to utilize unfamiliar resources (e.g. free range, new food) or to interact positively with strangers. We reasoned that if chickens became attached to certain odorants then incorporating these smells in otherwise unfamiliar situations might reassure them. Encouragingly, chicks were strongly attracted to a familiar odorant in a novel environment; this effect generalized to four odours (vanillin and the oils of orange, geranium and clove), four breeds and three methods of presentation (Jones and Carmichael, 1999b). Unless an odorant is found to be irritating, unpleasant or toxic, there may be no limit to this phenomenon.

Pairs of chicks reared with vanillin were then placed close together in a novel arena containing food and either the familiar odorant or a colour-matched odourless food dye (control). Whereas high fear levels inhibit social dispersal, exploration and feeding (Jones, 1996), the vanillin chicks moved apart sooner and further and were more likely to feed than the controls (Jones *et al.*, 2002a). This suggests that the presence of vanillin reduced fear. Next, although chicks normally avoid strangers, the presence of a familiar odorant increased social affiliation when unfamiliar chicks were placed together in a novel arena (see Jones, 2002). Finally, the diet is changed at various stages of a chicken's development and they are often reluctant to accept the new food (Vilarino *et al.*, 1998), perhaps because the novel features frighten them, food habits have become fixated, or they temporarily fail to recognize the new diet as food. Whatever the mechanism, even a transient hesitancy to feed may damage productivity and cause redirected pecking at drinkers or other birds, leading to problems such as diarrhoea, wet droppings and FP, respectively (Vilarino *et al.*, 1998). Encouragingly, chicks ate a novel food sooner if it was associated with a familiar smell (Jones, 2000).

Collectively, these findings confirm that chicks form olfactory memories and that familiar odours can serve as reassuring agents in otherwise unfamiliar situations. By reducing fear and making new resources more attractive, this sort of olfactory therapy could be a valuable husbandry tool.

ULTRAVIOLET LIGHT AS ENRICHMENT

Light and lighting systems are described in detail elsewhere in this book (Perry, Chapter 26; Prescott *et al.*, Chapter 15). For the present purposes, I focus specifically on the provision of ultraviolet (UV) light. Chickens see in the UV spectrum and within- and between-breed variation in the reflectance of UV_A light from their feathers may facilitate recognition of individuals and resources, e.g. substrates and feed. These capabilities might be compromised under the reduced spectral range of artificial lighting used in poultry housing (Prescott and Wathes, 1999). It was suggested that supplementary UV might be used as enrichment because turkeys preferred UV-enriched environments (Moinard and Sherwin, 1999) and UV supplementation (as part of a materially enriched environment) resulted in reduced inter-bird pecking (Sherwin *et al.*, 1999). Furthermore, basal corticosterone levels were higher (suggestive of chronic stress) in domestic chicks kept under UV-deficient rather than full-spectrum lighting (Maddocks *et al.*, 2001). However, further evidence of the beneficial effects of UV light is required because its provision may necessitate extensive modification of existing electrical installations (Lewis *et al.*, 2000).

ENRICHMENT THAT SUSTAINS LONG-TERM INTEREST AND REDUCES INTER-BIRD PECKING

Controllability is thought to be an important feature of enrichment (Sambrook and Buchanan-Smith, 1997). While video images and radio music exerted beneficial effects (see above) they offered the chickens little controllability over their environment. Therefore, we screened a number of intuitively attractive stimuli with which the birds could choose whether or not to interact and that would respond to them in some way, e.g. movement if pecked or nudged. More specifically, since FP may be misdirected environmental pecking (Blokhuis, 1986) and because chicks of a breed showing high FP directed more exploratory pecks at animate than inanimate stimuli (Blokhuis *et al.*, 2001), we reasoned that the provision of a sufficiently attractive inanimate target might serve to redirect pecking behaviour away from other birds.

Initially, we determined chickens' responses to different types of stimuli. Pairs of ISA Brown or Lohmann Brown chicks consistently pecked much more at bunches of string (white polypropylene baling twine) than at baubles, beads, tubing, chains, or feathers (Jones *et al.*, 2000b). They may have been attracted to string because it resembled a supernormal stimulus, like straw or worms, but it was manipulated differently from the other stimuli. As well as pecking and pulling at it they drew the string through their beaks and teased the strands apart, almost as if they were preening them. Thus, string may provide the most reinforcement. Indeed, chicks' interest in string outlasted that in commercially available devices (PECKA-BLOCKS) (see Jones, 2002) and string was manipulated so much by laying hens at a commercial farm that it soon resembled a ball of wool (Blokhuis *et al.*, 2001). It might be argued that the provision of string simply replaces one type of stereotyped pecking (FP) with another, but bouts of manipulating the string are relatively brief and the behavioural components are varied (peck, pull, tease strands apart).

Chickens have tetrachromatic vision (Rogers, 1995), so colour is likely to be an important feature. Colour preferences can vary according to the stimulus and the experimental context, but chicks and hens showed much greater interest in white or yellow strings than in green, blue or red ones (Jones *et al*., 2000b). These findings support suggestions that chickens find blue aversive and that red is a warning signal that causes alarm and avoidance. Furthermore, although visual complexity is normally attractive, white or yellow strings were pecked sooner and more often than combinations of white and yellow or of all five colours. Although chicks have a propensity to peck small, spherical, shiny objects (Rogers, 1995), incorporating silver beads into bunches of white string reduced pecking (Jones *et al*., 2000b), probably because the beads may have interfered with the chicks' ability to tease the strands apart. Next, chicks pecked static devices more than moving ones (Jones, 2002), perhaps because unpredictable movement elicited slight alarm and avoidance. Stimulus size was unimportant because devices varying in length and width (4–16 cm) were equally attractive. Clearly, chicks and hens are strongly attracted to stationary bunches of plain white string. Indeed, string sustained the interest of floor-housed hens over a 14-day period (Jones *et al*., 2002b) and birds housed from 1 day of age in pens containing string were still pecking it 17 weeks later (Jones, 2002). In this context, an automated system could be developed to detect waning of interest in the devices and to move them slightly in an attempt to rekindle interest.

The next step was to determine whether the provision of string could reduce injurious inter-bird pecking. First, trimming hens' feathers to reveal the white downy plumage normally elicits FP (McAdie and Keeling, 2000) but floor-housed hens pecked sooner and more often at string than at their trimmed or untrimmed companions (Jones *et al*., 2002b). Second, when groups of chicks from an experimental breed predisposed to show high levels of FP were given string from 1 day to 6 weeks of age they showed considerably less FP than controls (Blokhuis *et al*., 2001). Third, pecking-related feather damage was reduced when groups of caged laying hens were given string continuously from 1 day to 30 weeks of age, on transfer from rearing to laying cages at 16 weeks, or for 1 day every 4 weeks (Blokhuis *et al*., 2001). That the beneficial effects of enrichment on FP were apparent regardless of when string was provided seems inconsistent with the notion that early exposure is necessary for imprinting on to pecking stimuli (Huber-Eicher and Wechsler, 1997). However, chickens can revise their pecking preferences (Nicol *et al*., 2001) and any stimulation might be enough to decrease FP in the relatively barren environment of a commercial battery cage, regardless of the age at which it is applied. Similarly, enriching the environment either after brooding or at 16 weeks of age reduced psychogenic feather picking in caged parrots (Meehan *et al*., 2003). An additional benefit of enrichment was that it reduced the parrots' fear responses to unfamiliar human handlers as well as to novel objects (Meehan and Mench, 2002).

String sustained the interest of birds from four laying strains (ISA Brown, Lohmann Brown, Lohmann LSL, White Leghorn) and three types of housing (individual cages and floor pens in the laboratory and group cages at a commercial farm). However, field trials with different genotypes in alternative systems are required in order to confirm that its beneficial effects are not confined to particular breeds or housing systems. Although virtually no problems have been communicated to us, we must also determine the precise breaking strain of the string and

its nylon attachments, to prevent breakage and possible ingestion. Breaking strains may need to be varied according to species, strain and age. String has the added advantages of low cost, ready availability and ease of installation. For instance, bunches of string could be clipped to the roof of a cage so that they hung over the food trough. Suspending the devices from a web-like system of ropes that could be raised and lowered as required would minimize interfere with management practices or depopulation when birds are kept in large groups on the floor.

CONCLUSIONS

The opportunity to explore extraneous stimulation is important to chickens. Housing them in enriched environments may help to satisfy this requirement as well as exerting many other beneficial effects. However, rather than relying on human preconceptions of what an animal might find enriching we must establish the chickens' preferences for specific enrichment stimuli and then determine their effectiveness in reducing the expression of harmful behaviours. In any search for effective enrichment strategies we should also bear the following points in mind.

1. They must be practicable and affordable, otherwise the farmers will not use them.
2. We should visit the farms and involve the farmers at an early stage. For example, the use of string as an enrichment device grew from an observation of birds pecking at the twine round a bale of straw.
3. We can undoubtedly exercise our imagination but we should not overlook obvious or simple procedures, such as switching on the radio.
4. Positive interaction between the farmers and the animals in their charge represent a frequently overlooked form of enrichment; a procedure as simple as maintaining regular visual contact is a powerful way of reducing chickens' fear of people (Jones, 1996).
5. Strategies developed in the laboratory should always be tested in industry in order to promote technology transfer and to ensure that they generalize across different genotypes and housing systems.

Environmental enrichment is neither a substitute for the provision of resources required to satisfy behavioural needs, such as nesting and perching, nor a panacea for the welfare problems faced by farmed poultry. For example, although appropriate enrichment devices, e.g. bunches of string, can significantly reduce the expression of FP, they are unlikely to eradicate it. It is more productive to view practicable environmental enrichment as a valuable procedure that should ideally be integrated with other welfare-improvement strategies, such as positive human–animal interactions and selective breeding. However, in the short term, the provision of appropriate visual, auditory, olfactory and tactile enrichment can minimize the elicitation, expression and harmful consequences of behavioural states and behaviour patterns as varied as fear, boredom, FP and cannibalism. This, in turn, will help to improve the birds' welfare, productivity and profitability.

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REFERENCES

Blokhuis, H.J. (1986) Feather-pecking in poultry: its relation with ground pecking. *Applied Animal Behaviour Science* 16, 63–67.

Blokhuis, H.J., Jones, R.B., de Jong, I.C., Keeling, L.J. and Preisinger, R. (2001) Feather pecking: solutions through understanding. *Report of Seminars.* ID-Lelystad, Roslin Institute, SLU-Sweden; Lohmmann Tierzucht GmbH, Germany.

Bubier, N.E. (1996) The behavioural priorities of laying hens: the effects of two methods of environmental enrichment on time budgets. *Behavioural Processes* 37, 239–249.

Chamove, A.S. (1989) Environmental enrichment: a review. *Animal Technology* 40, 155–178.

Clarke, C.H. and Jones, R.B. (2000a) Domestic chicks' attraction to abstract video images: effects of stimulus movement, brightness, colour and complexity. *International Journal of Comparative Psychology* 13, 69–90.

Clarke, C.H. and Jones, R.B. (2000b) Responses of adult laying hens to abstract video images presented repeatedly outside the home cage. *Applied Animal Behaviour Science* 67, 97–110.

Craig, J.V. and Muir, W. (1998) Genetics and the behavior of chickens: welfare and productivity. In: Grandin, T. (ed.) *Genetics and the Behavior of Domestic Animals*. Academic Press, San Diego, California, pp. 265–297.

Faure, J.M., Bessei, W. and Jones, R.B. (2003) Direct selection for improvement of animal well-being. In: Muir, W.M. (ed.) *Poultry Genetics, Breeding and Biotechnology.* CAB International, Wallingford, UK.

Hemsworth, P.H. and Coleman, G.J. (1998) *Human–Livestock Interactions: The Stockperson and the Productivity and Welfare of Intensively Farmed Animals*. CAB International, Wallingford, UK.

Huber-Eicher, B. and Sebo, F. (2001) Reducing feather pecking when raising laying hens chicks in aviary systems. *Applied Animal Behaviour Science* 73, 59–68.

Huber-Eicher, B. and Wechsler, B. (1997) Feather pecking in domestic chicks: its relation to dustbathing and foraging. *Animal Behaviour* 54, 757–768.

Jones, R.B. (1996) Fear and adaptability in poultry: insights, implications and imperatives. *World's Poultry Science Journal* 52, 131–174.

Jones, R.B. (2000) Presence of a familiar odourant accelerates acceptance of novel food in domestic chicks. *International Journal of Comparative Psychology* 13, 147–153.

Jones, R.B. (2001) Environmental enrichment for poultry welfare. In: Wathes, C.M. (ed.) *Integrated Management Systems for Livestock.* British Society for Animal Sciences, Penicuik, Scotland. *Occasional Publication 28*, pp. 125–131.

Jones, R.B. (2002) Role of comparative psychology in the development of effective environmental enrichment strategies to improve poultry welfare. *International Journal of Comparative Psychology* 15, 1–29.

Jones, R.B. and Carmichael, N.L. (1999a) Can 'environmental enrichment' affect domestic chickens' preferences for one half of an otherwise symmetrical home cage? *Animal Welfare* 8, 159–164.

Jones, R.B. and Carmichael, N.L. (1999b) Domestic chicks are attracted to a familiar odorant in a novel test situation: a brief report. *Applied Animal Behaviour Science* 61, 351–356.

Jones, R.B. and Hocking, P.M. (1999) Genetic selection for poultry behaviour: big bad wolf or friend in need? *Animal Welfare* 8, 343–359.

Jones, R.B. and Rayner, S. (1999) Music in the hen house: a survey of its incidence and perceived benefits. *Poultry Science* 78 (S1), 110.

Jones, R.B. and Roper, T.J. (1997) Olfaction in the domestic fowl: a critical review. *Physiology and Behavior* 62, 1009–1018.

Jones, R.B. and Waddington, D. (1992) Modification of fear in domestic chicks, *Gallus gallus domesticus*, via regular handling and early environmental enrichment. *Animal Behaviour* 43, 1021–1033.

Jones, R.B., Carmichael, N.L. and Williams, C. (1998) Social housing and domestic chicks' responses to symbolic video images. *Applied Animal Behaviour Science* 56, 231–243.

Jones, R.B., Carmichael, N.L. and Rayner, E. (2000) Pecking preferences and pre-dispositions in domestic chicks: implications for the development of environmental enrichment devices. *Applied Animal Behaviour Science* 69, 291–312.

Jones, R.B., Facchin, L. and McCorquodale, C. (2002a) Social dispersal by domestic chicks in a novel environment: reassuring properties of a familiar odourant. *Animal Behaviour* 63, 659–666.

Jones, R.B., McAdie, T.M., McCorquodale, C. and Keeling, L.J. (2002b) Pecking at other birds and at string enrichment devices by adult laying hens. *British Poultry Science* 43, 337–343.

Kells, A., Dawkins, M.S. and Cortina Borja, M. (2001) The effect of a 'freedom food' enrichment on the behaviour of broilers on commercial farms. *Animal Welfare* 10, 347–356.

King, L.A. (2001) Environmental enrichment and aggression in commercial broiler breeder production. In: Garner, J.P., Mench, J.A. and Heekin, S.P. (eds) *Proceedings of the 35th International Congress of the International Society for Applied Ethology*, University of California, Davis, August 4–9, p. 174.

Lewis, P.D., Perry, G.C., Sherwin, C.M. and Moinard, C. (2000) Effect of ultraviolet radiation on the performance of intact male turkeys. *Poultry Science* 79, 850–855.

Lindberg, A.C. and Nicol, C.J. (1994) An evaluation of the effects of operant feeders on welfare of hens maintained on litter. *Applied Animal Behaviour Science* 41, 211–227.

Maddocks, S.A., Cuthill, I.C., Goldsmith, A.R. and Sherwin, C.M. (2001) Behavioural and physiological effects of absence of ultraviolet wavelengths for domestic chicks. *Animal Behaviour* 62, 1013–1019.

McAdie, T.M. and Keeling, L.J. (2000) Effect of manipulating feathers of laying hens on the incidence of feather pecking and cannibalism. *Applied Animal Behaviour Science* 68, 215–229.

McKenzie, R., Andrew, R.J. and Jones, R.B. (1998) Lateralization in chicks and hens: new evidence for control of response by the right eye system. *Neuropsychologia* 36, 51–58.

Meehan, C.L. and Mench, J.A. (2002) Environmental enrichment affects the fear and exploratory responses to novelty of young Amazon parrots. *Applied Animal Behaviour Science* 79, 75–88.

Meehan, C.L., Millam, J.R. and Mench, J.A. (2003) Foraging opportunity and increased physical complexity both prevent and reduce psychogenic feather picking by young Amazon parrots. *Applied Animal Behaviour Science* 80, 71–85.

Mench, J.A. (1994) Environmental enrichment and exploration. *Laboratory Animal*, February, 38–41.

Moinard, C. and Sherwin, C.M. (1999) Turkeys prefer fluorescent light with supplementary ultraviolet radiation. *Applied Animal Behaviour Science* 64, 261–267.

Newberry, R.C. (1999) Exploratory behaviour of young domestic fowl. *Applied Animal Behaviour Science* 63, 311–321.

Nicol, C.J. (1992) Effects of environmental enrichment and gentle handling on behaviour and fear responses of transported broilers. *Applied Animal Behaviour Science* 33, 367–380.

Nicol, C.J. and Guildford, T. (1991) Exploratory activity as a measure of motivation in deprived hens. *Animal Behaviour* 41, 333–341.

Nicol, C.J., Lindberg, A.C., Phillips, A.J., Pope, S.J., Wilkins, L.J. and Green, L.E. (2001) Influence of prior exposure to wood shavings on feather pecking, dustbathing and foraging in adult laying hens. *Applied Animal Behaviour Science* 73, 141–155.

Platt, D.M. and Novak, M.A. (1997) Video stimulation as enrichment for captive rhesus monkeys *Macaca mulatta*. *Applied Animal Behaviour Science* 52, 139–155.

Prescott, N.B. and Wathes, C.M. (1999) Reflective properties of domestic fowl (*Gallus g. domesticus*), the fabric of their housing and the characteristics of the light environment in environmentally controlled poultry houses. *British Poultry Science* 40, 185–193.

Rogers, L.J. (1995) *The Development of Brain and Behaviour in the Chicken*. CAB International, Wallingford, UK.

Sambrook, T.D. and Buchanan-Smith, H.M. (1997) Control and complexity in novel object enrichment. *Animal Welfare* 6, 207–216.

Sherwin, C.M., Lewis, P.D. and Perry, G.C. (1999) Effects of environmental enrichment, fluorescent and intermittent lighting on injurious pecking amongst male turkey poults. *British Poultry Science* 40, 592–598.

Vilarino, M., Leon, A., Faure, J.M. and Picard, M. (1998) Ability of broiler chicks to detect hidden food. *Archiv für Geflugelkunde* 62, 156–162.

Webster, J. (1994) *Animal Welfare: a Cool Eye Towards Eden*. Blackwell Science, Oxford, UK.

CHAPTER 21
Feather pecking and feather loss

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ABSTRACT

Feather pecking is a major welfare problem in laying hens. Plumage condition is also affected by other causes of feather loss, such as abrasion and moulting. There are different forms of pecking behaviour in laying hens. There is evidence that feather pecking is redirected ground pecking, indicating that floor substrate availability and quality plays an important role in the development of feather pecking. Other environmental factors that affect the development of feather pecking are group size and stocking density, food form, light intensity and colour, and rearing conditions. Furthermore, genetic background plays an important role. Feather pecking may also be related to other behavioural characteristics in laying hens, such as reaction to frustration and stress, fearfulness and sociality. If feather peckers can be characterized, this would provide viable information on the causation of feather pecking. Furthermore, fear or stress measures may be used as predictors of propensity to develop feather pecking in breeding populations. Characterizing feather peckers seems a viable approach towards a better understanding of the problem of feather pecking. With our current state of knowledge on the causation of feather pecking, the environmental factors that influence the development of feather pecking and the characteristics of feather peckers and non-feather peckers, it should be possible to achieve more control over the problem of feather pecking in European flocks.

INTRODUCTION

Feather pecking causes major welfare problems in laying hens. Feather pecking may lead to severe feather damage and heat loss for the victim. Bald patches can attract tissue pecking, which may result in cannibalism and even death of the victim. Feather pecking is observed both in cages and in large group-housing systems. However, the problem is more difficult to control in large group-housing systems because it can spread more easily through the flock. Feather damage and feather loss are also affected by abrasion caused by the housing system. In addi-

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tion, natural processes such as moulting should be taken into account when evaluating plumage condition. This chapter focuses on feather pecking and related behavioural characteristics, looking at plumage condition, the different forms of feather pecking, the causation of feather pecking and the environmental factors that influence feather pecking behaviour. The relationship with other behavioural characteristics, such as reaction to frustration and stress, fearfulness and sociality, will also be discussed. The aim of this chapter is to give an overview of the problem of feather pecking and feather loss in laying hens and to explore possible solutions for the problem. A better control over the problem of feather pecking would have major welfare implications, especially in large group-housing systems.

PLUMAGE CONDITION

Apart from feather pecking, feather damage and feather loss are also affected by abrasion caused by the housing system. Furthermore, natural processes such as moulting should also be taken into account when evaluating plumage condition. McKeegan and Savory (1999) studied the relationship between feather eating and feather pecking and found that feathers cast during a juvenile moult at 9–11 weeks were eaten during the subsequent weeks. They suggested that once all the feathers on the floor have been removed, this causes redirection of pecking from feathers on the floor to other birds. Hughes (1980) evaluated plumage condition in hens housed in individual cages with and without birds present in adjacent cages and found that most feather damage was due to abrasion. In the situation with birds in adjacent cages, feather damage was more severe, due to feather pecking, resulting in higher maintenance requirements. Freire *et al*. (1999) showed that cage design also affects feather condition; in groups with an elevated feed trough, feather cover was better than in groups with a conventional feed trough. This was caused by the fact that birds were prevented from stepping from the perch on to the back of a feeding bird and from dustbathing near the feed trough. Furthermore, more feather pecking was observed in conventional cages than in cages with an elevated trough, possibly due to the fact that feather damage can attract feather pecking. McAdie and Keeling (2000) showed that birds with scruffy, damaged or missing feathers are more attractive to peck at than birds with intact feathers.

Evaluation of plumage and body condition can be a valuable tool to assess the extent of problems with feather pecking and cannibalism in a flock of birds. Bilcík and Keeling (1999) studied the relationship between receiving pecks and feather damage in victims of feather pecking, recording the type of pecking (discussed in the next paragraph) and the body part that was pecked. They found a relationship between plumage condition and severe feather pecks received. Furthermore, most feather pecking was observed on the tail, the rump and the back. Damage to the underside of the neck, the primary wing feathers and the tail should be attributed partly to abrasion.

FEATHER PECKING

Feather pecking in laying hens can be characterized as pecking at and pulling out the feathers of conspecifics. Different types of bird-to-bird pecking can be

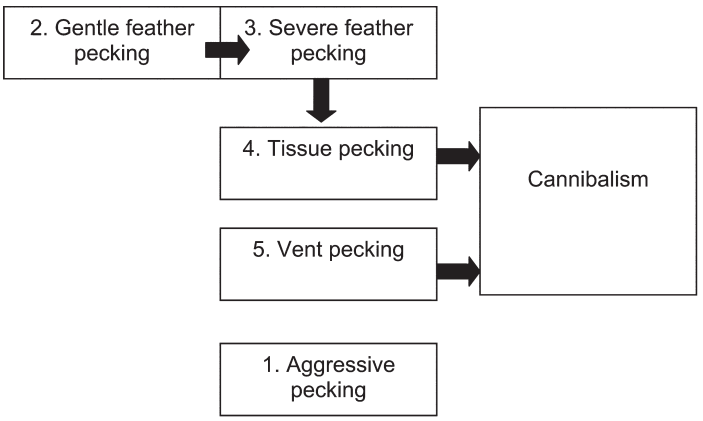

Fig. 21.1. Forms of bird-to-bird pecking (classification after Savory, 1995).

distinguished. In a workshop at the 9th European Poultry Conference in Glasgow (1994) a classification of pecking behaviour was proposed, categorizing five types of bird-to-bird pecking based on both cause and effect (Savory, 1995). The five types distinguished were:

1. Aggressive pecking.
2. Gentle feather pecking without removal of feathers.
3. Severe feather pecking leading to feather loss.
4. Tissue pecking in denuded areas.
5. Vent pecking (see Fig. 21.1).

Aggressive pecking is used to establish a stable dominance hierarchy. It may lead to some damage to the head and neck region, but it should not be confused with feather pecking behaviour.

Feather pecking without removal of feathers, or *gentle feather pecking*, sometimes appears to be directed at litter particles on the plumage, but can also develop into stereotypic pecking with a high frequency. It can cause some damage but is often ignored by the recipient.

Severe feather pecking or feather pulling is characterized by forceful pecking at or pulling out of feathers, to which the victim usually reacts. Feather removal has been shown to be painful (Gentle and Hunter, 1990). Feathers that are pulled out are sometimes eaten. Severe feather pecking or pulling causes feather damage and can lead to bald patches. These bald patches may attract *tissue pecking*, which can result in wounding of the victim and cannibalism, i.e. the consumption of flesh or blood.

Vent pecking is often seen around the onset of lay and is directed at the prolapsed uterus and the feathers around it. Vent pecking may start as investigative pecking, but can also lead to cannibalism when the uterus is damaged or the internal organs are pulled out.

Gentle feather pecking, severe feather pecking and tissue pecking are not completely clear-cut and may grade into each other (Savory, 1995). In a recent paper, McAdie and Keeling (2002) suggested that, in adult laying hens, gentle

feather pecking may develop into stereotyped gentle feather pecking and severe feather pecking by either increased frequency or increased severity of bird-to-bird pecks. If this is indeed the case, gentle feather pecking early in life may be an indicator of severe feather pecking in adult laying hens.

CAUSATION OF FEATHER PECKING

Laying hens have several different behavioural systems motivated by separate causal factors, such as foraging and dustbathing. There is evidence that these behavioural systems can be redirected or misdirected at other substrates, for instance a bird may redirect its ground pecking behaviour at the feathers of other birds. Knowledge of the motivational background of feather pecking gives us clues about the causal factors that lead to feather pecking; if feather pecking is redirected ground pecking, substrate quality and availability are likely to be important factors in the development of feather pecking. There is an ongoing debate on the causation of feather pecking. Feather pecking is often thought to be a form of redirected behaviour, developing either from ground pecking (Blokhuis, 1986) or pecking during dustbathing (Vestergaard and Lisborg, 1993). Blokhuis and Arkes (1984) showed that birds housed on slatted floors showed more feather pecking and less ground pecking than birds housed on litter. Moreover, when birds housed on litter were transferred to slatted floors, feather pecking increased in these birds. These results support the hypothesis that ground pecks are redirected at feathers when no suitable substrate is available (Blokhuis and Arkes, 1984). Vestergaard and Lisborg (1993) showed that chicks that are trained to dust bathe on feathers instead of sand continued to dust bathe on and peck at feathers later in life, even if they could choose between sand and feathers. It was proposed that chicks that miss early experience with substrates such as sand or peat for dustbathing may develop a preference for feathers as a pecking and dustbathing substrate (Vestergaard *et al*., 1993). Huber-Eicher and Wechsler (1997), however, showed that the provision of sand did not prevent feather pecking, whereas the provision of straw led to a reduction in feather pecking. Furthermore, feather pecking was inversely related to foraging activity, but not to dustbathing activity (Huber-Eicher and Wechsler, 1997). When the demand for straw and feathers as a floor substrate was assessed, all hens worked for straw, but only some for feathers (Gunnarsson *et al*., 2000).

GENETIC FACTORS

Line differences in plumage condition (Ambrosen and Petersen, 1997; Wahlstrom *et al*., 2001) and in feather pecking behaviour (Hughes and Duncan, 1972) suggest that genetic background plays a role. Selection against feather pecking has been shown to be feasible (Muir, 1996; Kjaer *et al*., 2001). Kjaer *et al*. (2001) successfully used individual selection on feather pecking behaviour to create a high and a low feather pecking line. Muir (1996) used group selection to reduce problems with cannibalism. Mortality was reduced from 68% in generation 2 to 9% in generation 6 using group selection on production-related traits (Muir, 1996). The genetic factors influencing feather pecking are discussed further by Kjaer and Hocking (this volume, Chapter 12).

ENVIRONMENTAL FACTORS

Environmental factors that influence the development of feather pecking are floor substrate availability and quality (as discussed above), group size and stocking density, food form, light intensity and colour, and rearing conditions. In large groups more feather pecking was observed than in small groups (Allen and Perry, 1975), whereas Savory *et al*. (1999) found most feather damage in large groups with a high stocking density. In a study by Nicol *et al*. (1999) in percheries, levels of gentle feather pecking and the amount of feather damage increased with higher stocking density and larger group size. Gentle feather pecking was mainly seen on the floor and on the perches, whereas severe feather pecking was observed mostly around the nestboxes. Feather pecking is observed in cages as well as in large group-housing systems (Appleby and Hughes, 1991). In large group-housing systems, however, the problem is more difficult to control, as feather pecking may spread by social transmission (Zeltner *et al*., 2000). Furthermore, food form affects feather pecking. Birds that were fed pellets showed more feather pecking than birds fed mash (Aerni *et al*., 2000). Kjaer and Vestergaard (1999) showed that light intensity affected feather pecking. Gentle feather pecking developed more often in groups with a low light intensity, whereas severe feather pecking was seen more under high light intensity. Feather pecking can also vary during the day, as Kjaer (2000) found an increase of feather pecking over the day, between 8 and 14 h after lights-on. Light colour may also play a role, as D'Eath and Stone (1999) showed that light colour affects social behaviour in laying hens. Rearing conditions may affect the propensity to develop feather pecking as well; the presence of a mother hen, in particular, is frequently mentioned. Roden and Wechsler (1998) showed that the presence of a hen during the rearing period increased the activity of the chicks. They did not find a difference in feather pecking between birds from different rearing conditions, however. When risk factors for feather pecking were identified in a epidemiological study, extensive use of an outdoor hen-run, litter availability, and use of bell drinkers (instead of nipple drinkers) were factors that reduced the risk of feather pecking (Green *et al*., 2000).

RELATIONSHIP WITH OTHER BEHAVIOURAL CHARACTERISTICS

Feather pecking may be related to other behavioural characteristics. If feather peckers can be characterized, this would provide us with viable information on the causation of feather pecking. Frustration, i.e. the absence of an expected reward, may play a role in the development of feather pecking. Duncan and Wood-Gush (1972) showed that frustration of feeding behaviour leads to high levels of pecking at the covered feeder and at other parts of the cage. Lindberg and Nicol (1994) supplied hens with operant feeders to reduce problems with feather pecking. They hypothesized that the birds would direct more pecks at the operant feeding devices and less at other birds. Unexpectedly, birds with operant feeders developed higher levels of feather pecking than birds with normal feeders. Lindberg and Nicol (1994) proposed a model in which frustration (caused when, for instance, a bird tries to reach the operant feeder but is unsuccessful) results in increased arousal, aggression and fear. Under these circumstances, occasional pecks at the plumage of other birds may develop into more damaging forms of feather pecking. Taylor *et*

al. (2001) studied the effect of giving birds operant control over food and light and found that groups with operant control did not show more feather pecking than control groups. In their study, however, groups consisted of only five birds, as compared to groups of 80 birds in the study by Lindberg and Nicol (1994). In the study by Taylor *et al*. (2001), each bird should be able to reach and operate the feeder, avoiding frustration and frustration-induced pecking.

Feather pecking has also been associated with fearfulness (Hughes and Duncan, 1972; Vestergaard *et al*., 1993), with open-field response (Jones *et al*., 1995) and with coping strategy (Korte *et al*., 1997). Hughes and Duncan (1972) showed that birds in cages with the most feather damage were also the most fearful, whereas Vestergaard *et al*. (1993) actually showed that the birds performing feather pecking were most fearful, as assessed by their tonic immobility. No relationship was found, however, between feather pecking and response to a novel object (Albentosa *et al*., 2003).

Jones *et al*. (1995) showed that young chicks from a low feather pecking (LFP) line vocalized and walked sooner in an open-field than chicks from a high feather pecking (HFP) line, and suggested that this reflects differences in social motivation to return to their flock mates. Korte *et al*. (1997) showed that birds from these same HFP and LFP lines showed differences in stress response after manual restraint. LFP birds showed a stronger corticosterone response than HFP birds, whereas HFP birds showed a larger plasma noradrenaline response. From these results, Korte *et al*. (1997) suggested that these lines may have different coping strategies, as found in rodents: proactive (fight/flight) and reactive (conservation/withdrawal) copers (Koolhaas *et al*., 1999). Korte *et al*. (1997) proposed that birds from the HFP line may be characterized as proactive copers and birds from the LFP line as reactive copers.

DUTCH RESEARCH PROGRAMME ON FEATHER PECKING

A multidisciplinary research programme on feather pecking in laying hens was started in The Netherlands in 1999. Physiological, ontogenetic, genetic and behavioural aspects of feather pecking were integrated in this programme as a combined effort of three research institutes. In this programme the HFP and LFP lines that were also studied by Korte *et al*. (1997) and Jones *et al*. (1995) were used as a model to study feather pecking. These lines are selection lines from a commercial breeder in The Netherlands. They were selected for production-related traits and also showed a consistent difference in feather pecking behaviour. Differences in pecking behaviour between HFP and LFP birds may be explained by the hypothesis that these birds have different coping strategies. The aim of this programme was to characterize feather peckers and non-feather peckers to better understand the underlying mechanisms of feather pecking. This knowledge will help us to solve the problem of feather pecking in European flocks.

Physiological Characteristics

Van Hierden *et al*. (2002a,b) studied the relationship between the development of feather pecking and physiological and neurobiological characteristics of laying

hens. They studied adrenocortical (re)activity and dopamine and serotonin turnover after manual restraint (van Hierden *et al*., 2002b). Plasma corticosterone levels were lower in HFP chicks, as was found previously by Korte *et al*. (1997). Both dopamine and serotonin turnover were lower in HFP chicks as well. These differences in physiological and neurobiological characteristics fit well with the differences found in rodents with different coping strategies, i.e. proactive and reactive animals.

Ontogeny

The ontogenetic aspects of feather pecking include the development and causation of pecking. Riedstra and Groothuis (2002) found that gentle feather pecking was already present on the first day after hatching. They studied the relationships with other pecking behaviours and found that feather pecking was associated with socially oriented pecks, rather than with ground pecking. When birds were regularly confronted with unfamiliar birds, gentle feather pecking increased, compared with control groups, and most pecks were directed at the unfamiliar birds. The groups that were regularly confronted with unfamiliar birds were also more fearful, as assessed by their tonic immobility, indicating that these confrontations are stressful and that stress may encourage feather pecking. From these results, Riedstra and Groothuis (2002) argued that gentle feather pecking at an early age reflects social exploration rather than redirected ground pecking. It remains unclear, however, how feather pecking at a young age is related to feather pecking as an adult.

The presence or absence of a mother hen may also affect feather pecking and related characteristics. Rodenburg *et al*. (2004a) studied feather pecking in birds that had been reared in a large group without a hen present and birds that had been reared in a small group with a foster hen. The results from the feather pecking observations, although limited, indicate that birds from the HFP line from semi-commercial rearing conditions show more feather pecking than HFP birds from semi-natural rearing conditions.

Genetic Regions

Buitenhuis *et al*. (2003a,b, 2004) performed a quantitative trait loci (QTL) analysis on feather pecking, receiving feather pecking, stress response and open-field behaviour to identify the genetic regions involved in these traits. A QTL is a statistical association between a phenotypic trait (for instance, gentle feather pecking) and a chromosomal region. Genetic regions, or QTL, were found for both gentle and severe feather pecking. Different QTL were detected in young chicks and in adults, indicating that feather pecking at a young age and as an adult are separate traits. A separate QTL was also found affecting stress response (Buitenhuis *et al*., 2003a). For open-field behaviour, QTL were identified both in young and in adult birds; again there was no overlap between ages (Buitenhuis *et al*., 2004).

When genetic parameters of feather pecking and open-field response were estimated in the cross population described previously, gentle feather pecking and open-field behaviour were found to be heritable (Rodenburg *et al*., 2003).

Behavioural Characteristics

Van Hierden *et al*. (2002a) studied the development of feather pecking in the first 8 weeks of life and found that HFP birds showed higher levels of gentle feather pecking and preening, whereas LFP birds spent more time feeding and foraging. Similar results were found by Rodenburg and Koene (2003) in HFP and LFP birds studied from 7 until 33 weeks of age. Van Hierden *et al*. (2002a) suggested that HFP and LFP birds have different ways of targeting pecking behaviour.

Rodenburg and Koene (2003) studied the importance of the social environment in the development of feather pecking. They compared feather pecking in the home-pen with feather pecking in three feather pecking tests: one individual test with a bunch of feathers and two social tests (with whole group), one with and one without a bunch of feathers. Birds that showed feather pecking in the home-pen also showed feather pecking in the social test. Bunch pecking in the individual test, however, was not a good measure of feather pecking in the home-pen. Furthermore, LFP birds showed more bunch pecking than HFP birds, which is not in agreement with the differences found in feather pecking in the home-pen. HFP and LFP birds also reacted differently to the repeated testing (tests were performed at ten different ages) in the individual test: HFP birds showed a sharp increase in number of vocalizations over time, whereas LFP birds showed a decrease. These differences fit with the hypothesis that feather pecking is related to other behavioural characteristics.

HFP and LFP birds were also tested under conditions of frustration in a Skinner box, to investigate whether the line difference in feather pecking could be explained from an underlying difference in reaction to frustration (Rodenburg *et al*., 2002, 2004a). Contrary to our expectations, LFP birds showed a stronger reaction to frustration (presentation of a covered food reward) than HFP birds, expressed in key pecking and covered feeder pecking. When a bunch of feathers was presented during frustration, little pecking on the bunch was observed. It was hypothesized that HFP birds may have lacked an appropriate substrate to redirect pecking at, i.e. feathers presented in a different manner or other birds (Rodenburg *et al*., 2002). However, when feathers were presented in a different manner, namely around one of the keys of the Skinner box, all birds avoided this key. From this, we concluded that bunches of feathers or feathers fixed to the Skinner box could not facilitate feather pecking (Rodenburg *et al*., 2004a). Finally, birds were presented with a frustrating situation in a Skinner box in the presence of another bird, to discover whether frustration would facilitate feather pecking. In this study, we found that short-term frustration in a Skinner box did not facilitate feather pecking. However, differences in reaction to frustration between HFP and LFP birds indicate that frustration may still play a role in the development of feather pecking.

When genetic parameters for feather pecking and open-field behaviour were estimated, a genetic correlation was found between open-field activity and pecking behaviour. This indicated that birds with a high activity in the open field at a young age, showed little pecking behaviour as adults. Furthermore, low open-field activity at a young age was correlated with high open-field activity as an adult (Rodenburg *et al*., 2004b). These results fit well with the results of Jones *et al*. (1995), where LFP chicks were more active in the open field than HFP chicks. As adults, HFP birds vocalized more than LFP birds in an individual test

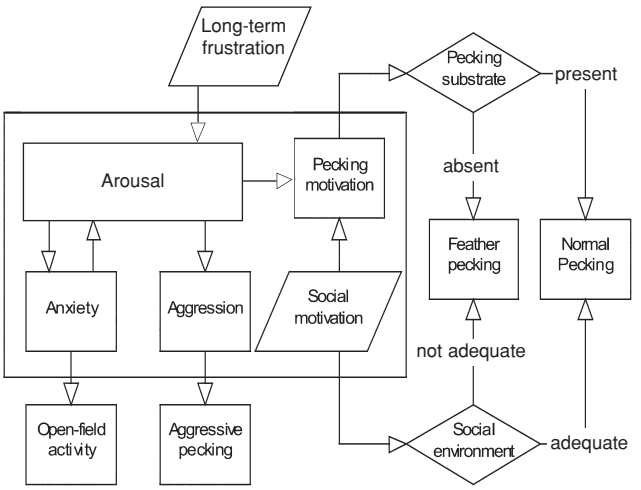

Fig. 21.2. Synthesis of the model from Lindberg and Nicol (1994) on the role of frustration in the development of feather pecking and the results from our study.

(Rodenburg and Koene, 2003), confirming our finding that birds that have low open-field activity at a young age may have high open-field activity as adults. Thus, birds with a low open-field activity at a young age and a high open-field activity at an adult age show lower levels of pecking behaviour as adults, resembling the HFP line. This suggests that feather peckers are indeed more fearful and have a lower social motivation than non-feather peckers.

The results from these studies were used to propose a new model on the role of frustration in the development of feather pecking (Fig. 21.2), adapted from the model described by Lindberg and Nicol (1994). From our experiments we can conclude that short-term frustration in a Skinner box does not facilitate feather pecking. Long-term frustration was kept in the model, as Lindberg and Nicol (1994) showed that this can lead to feather pecking.

Furthermore, the social environment plays an important role in the development of feather pecking. Bunches of feathers in an individual setting were not comparable with feather pecking in a social context. Differences in social motivation can explain differences in feather pecking. Birds from the LFP line have a stronger social motivation than HFP birds, as assessed by their open-field activity. Hence, LFP birds are more 'in touch' with their social environment and are less likely to develop high levels of feather pecking. We also found that feather pecking still developed, even when substrates for ground pecking or food pecking were available, especially in birds from the HFP line. It may be that HFP and LFP birds have a different perception of their environment. HFP birds may indeed be more animal-directed in their pecking behaviour and LFP birds more (abiotic) environment-directed. Finally, we were unable to find direct relationships between feather pecking and coping strategy. A relationship was found between early open-field behaviour and later pecking behaviour, indicating that fearfulness and social motivation affect pecking behaviour; fearful birds with a low social motivation being the birds with the largest propensity to develop feather pecking.

CONCLUSIONS

Characterizing feather peckers seems a viable approach to a better understanding of the problem of feather pecking. With the current knowledge available on the causation of feather pecking, the environmental factors that influence the development of feather pecking, and the characteristics of feather peckers and non-feather peckers, it should be possible to attain more control over the problem of feather pecking. The identification of genetic regions involved in feather pecking and related characteristics may provide us with the tools to breed birds that have a reduced propensity to develop feather pecking. The relationship between open-field behaviour of young chicks and pecking behaviour of adult birds presents us with possibilities for identifying possible feather peckers at a young age. Finally, the present knowledge on risk factors and causation of feather pecking should enable us to develop housing systems for laying hens that provide birds with enough space and behavioural possibilities to decrease the risk of feather pecking.

REFERENCES

Aerni, V., El-Lethey, H. and Wechsler, B. (2000) Effect of foraging material and food form on feather pecking in laying hens. *British Poultry Science* 41, 16–21.

Albentosa, M.J., Glen, E., Leeb, C., Whittaker, X. and Nicol, C.J. (2003) An evaluation of response to novelty as a predictor of pecking tendency in laying hens. *Applied Animal Behaviour Science* 82, 313–328.

Allen, J. and Perry, G.C. (1975) Feather pecking and cannibalism in a caged layer flock. *British Poultry Science* 16, 441–451.

Ambrosen, T. and Petersen, V.E. (1997) The influence of protein level in the diet on cannibalism and quality of plumage of layers. *Poultry Science* 76, 559–563.

Appleby, M.C. and Hughes, B.O. (1991) Welfare of laying hens in cages and alternative systems: environmental, physical and behavioural aspects. *World's Poultry Science Journal* 47, 108–128.

Bilcík, B. and Keeling, L.J. (1999) Changes in feather condition in relation to feather pecking and aggressive behaviour in laying hens. *British Poultry Science* 40, 444–451.

Blokhuis, H.J. (1986) Feather-pecking in poultry: its relation with ground-pecking. *Applied Animal Behaviour Science* 16, 63–67.

Blokhuis, H.J. and Arkes, J.G. (1984) Some observations on the development of feather-pecking in poultry. *Applied Animal Behaviour Science* 12, 145–157.

Buitenhuis, A.J., Rodenburg, T.B., Hierden, Y.M. v., Siwek, M., Cornelissen, S.J.B., Nieuwland, M.G.B., Koene, P., Korte, S.M., Bovenhuis, H. and van der Poel, J.J. (2003a) Mapping quantitative trait loci affecting feather pecking behavior and stress response in laying hens. *Poultry Science* 82, 1215–1222.

Buitenhuis, A.J., Rodenburg, T.B., Siwek, M., Cornelissen, S.J.B., Nieuwland, M.G.B., Crooijmans, R.P.M.A., Groenen, M.A.M., Koene, P., Bovenhuis, H. and van der Poel, J.J. (2003b) Identification of quantitative trait loci for receiving pecks in young and adult laying hens. *Poultry Science* 82, 1661–1667.

Buitenhuis, A.J., Rodenburg, T.B., Siwek, M., Cornelissen, S.J.B., Nieuwland, M.G.B., Crooijmans, R.P.M.A., Groenen, M.A.M., Koene, P., Bovenhuis, H. and van der Poel, J.J. (2004) Identification of QTL involved in open-field behavior in young and adult laying hens. *Behavior Genetics* 34, 325–333.

D'Eath, R.B. and Stone, R.J. (1999) Chickens use visual cues in social discrimination: an experiment with coloured lighting. *Applied Animal Behaviour Science* 62, 233–242.

Duncan, I.J.H. and Wood-Gush, D.G.M. (1972) Thwarting of feeding behaviour in the domestic fowl. *Animal Behaviour* 20, 444–451.

Freire, R., Walker, A. and Nicol, C.J. (1999) The relationship between through height, feather cover and behaviour of laying hens in modified cages. *Applied Animal Behaviour Science* 63, 55–64.

Gentle, M.J. and Hunter, L.N. (1990) Physiological and behavioural responses associated with feather removal in *Gallus gallus* var *domesticus*. *Research in Veterinary Science* 50, 95–101.

Green, L.E., Lewis, K., Kimpton, A. and Nicol, C.J. (2000) Cross-sectional study of the prevalence of feather pecking in laying hens in alternative systems and its associations with management and disease. *Veterinary Record* 147, 233–238.

Gunnarsson, S., Matthews, L.R., Foster, T.M. and Temple, W. (2000) The demand for straw and feathers as litter substrates by laying hens. *Applied Animal Behaviour Science* 65, 321–330.

Hüber-Eicher, B. and Wechsler, B. (1997) Feather pecking in domestic chicks: its relation to dustbathing and foraging. *Animal Behaviour* 54, 757–768.

Hughes, B.O. (1980) Feather damage in hens caged individually. *British Poultry Science* 21, 149–154.

Hughes, B.O. and Duncan, I.J.H. (1972) The influence of strain and environmental factors upon feather pecking and cannibalism in fowls. *British Poultry Science* 13, 525–547.

Jones, R.B., Blokhuis, H.J. and Beuving, G. (1995) Open-field and tonic immobility responses in domestic chicks of two genetic lines differing in their propensity to feather peck. *British Poultry Science* 36, 525–530.

Kjaer, J.B. (2000) Diurnal rhythm of feather pecking behaviour and condition of integument in four strains of loose housed laying hens. *Applied Animal Behaviour Science* 65, 331–347.

Kjaer, J.B. and Vestergaard, K.S. (1999) Development of feather pecking in relation to light intensity. *Applied Animal Behaviour Science* 62, 243–254.

Koolhaas, J.M., Korte, S.M., De Boer, S.F., Van Der Vegt, B.J., Van Reenen, C.G., Hopster, H., De Jong, I.C., Ruis, M.A.W. and Blokhuis, H.J. (1999) Coping styles in animals: current status in behavior and stress-physiology. *Neuroscience and Biobehavioural Reviews* 23, 925–935.

Korte, S.M., Beuving, G., Ruesink, W. and Blokhuis, H.J. (1997) Plasma catecholamine and corticosterone levels during manual restraint in chicks from a high and low feather pecking line of laying hens. *Physiology and Behaviour* 62, 437–441.

Lindberg, A.C. and Nicol, C.J. (1994) An evaluation of the effect of operant feeders on welfare of hens maintained on litter. *Applied Animal Behaviour Science* 41, 211–227.

McAdie, T.M. and Keeling, L.J. (2000) Effect of manipulating feathers of laying hens on the incidence of feather pecking and cannibalism. *Applied Animal Behaviour Science* 68, 215–229.

McAdie, T.M. and Keeling, L.J. (2002) The social transmission of feather pecking in laying hens: effects of environment and age. *Applied Animal Behaviour Science* 75, 147–159.

McKeegan, D.E.F. and Savory, C.J. (1999) Feather eating in layer pullets and its possible role in the aetiology of feather pecking damage. *Applied Animal Behaviour Science* 65, 73–85.

Muir, W.M. (1996) Group selection for adaptation to multiple-hen cages: selection program and direct responses. *Poultry Science* 75, 447–458.

Nicol, C.J., Gregory, N.G., Knowles, T.G., Parkman, I.D. and Wilkins, L.J. (1999) Differential effects of increased stocking density, mediated by increased flock size, on feather pecking and aggression in laying hens. *Applied Animal Behaviour Science* 65, 137–152.

Riedstra, B. and Groothuis, T.G.G. (2002) Early feather pecking as a form of social exploration: the effect of group stability on feather pecking and tonic immobility in domestic chicks. *Applied Animal Behaviour Science* 77, 127–138.

Roden, C. and Wechsler, B. (1998) A comparison of the behaviour of domestic chicks reared with or without a hen in enriched pens. *Applied Animal Behaviour Science* 55, 317–326.

Rodenburg, T.B. and Koene, P. (2003) Comparison of individual and social feather pecking tests in two lines of laying hens at ten different ages. *Applied Animal Behaviour Science* 81, 133–148.

Rodenburg, T.B., Zimmerman, P.H. and Koene, P. (2002) Reaction to frustration in high and low feather pecking laying hens. *Behavioural Processes* 59, 121–129.

Rodenburg, T.B., Buitenhuis, A.J., Ask, B., Uitdehaag, K.A., Koene, P., van der Poel, J.J. and Bovenhuis, H. (2003) Heritability of feather pecking and open-field response in laying hens at two different ages. *Poultry Science* 82, 861–867.

Rodenburg, T.B., Koene, P. and Spruijt, B.M. (2004a) Reaction to frustration in high and low feather pecking lines of laying hens from commercial or semi-natural rearing conditions. *Behavioural Processes* 65, 179–188.

Rodenburg, T.B., Buitenhuis, A.J., Ask, B., Uitdehaag, K.A., Koene, P., van der Poel, J.J., van Arendonk, J.A.M. and Bovenhuis, H. (2004b) Genetic and phenotypic correlations between feather pecking and open-field response in laying hens at two different ages. *Behaviour Genetics* 34, 407–415.

Savory, C.J. (1995) Feather pecking and cannibalism. *World's Poultry Science Journal* 51, 215–219.

Savory, C.J., Mann, J.S. and Macleod, M.G. (1999) Incidence of pecking damage in growing bantams in relation to food form, group size, stocking density, dietary tryptophan concentration and dietary protein source. *British Poultry Science* 40, 579–584.

Taylor, P.E., Coerse, N.C.A. and Haskell, M. (2001) The effects of operant control over food and light on the behaviour of domestic hens. *Applied Animal Behaviour Science* 71, 319–333.

van Hierden, Y.M., Korte, S.M., Ruesink, E.W., van Reenen, C.G., Engel, B., Koolhaas, J.M. and Blokhuis, H.J. (2002a) The development of feather pecking behaviour and targeting of pecking in chicks from a high and low feather pecking line of laying hens. *Applied Animal Behaviour Science* 77, 183–196.

van Hierden, Y.M., Korte, S.M., Ruesink, E.W., van Reenen, C.G., Engel, B., Korte-Bouws, G.A.H., Koolhaas, J.M. and Blokhuis, H.J. (2002b) Adrenocortical reactivity and central serotonin and dopamine turnover in young chicks from a high and low feather-pecking line of laying hens. *Physiology and Behaviour* 75, 653–659.

Vestergaard, K.S. and Lisborg, L. (1993) A model of feather pecking development which relates to dustbathing in the fowl. *Behaviour* 126, 291–308.

Vestergaard, K.S., Kruijt, J.P. and Hogan, J.A. (1993) Feather pecking and chronic fear in groups of red junglefowl: their relations to dustbathing, rearing environment and social status. *Animal Behaviour* 45, 1127–1140.

Wahlstrom, A., Tauson, R. and Elwinger, K. (2001) Plumage condition and health of aviary-kept hens fed mash or crumbled pellets. *Poultry Science* 80, 266–271.

Zeltner, E., Klein, T. and Hüber-Eicher, B. (2000) Is there social transmission of feather pecking in groups of laying hen chicks? *Animal Behaviour* 60, 211–216.

CHAPTER 22
Cannibalism

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ABSTRACT

Cannibalism is a serious welfare problem in laying hens which can cause high mortality. Cannibalistic behaviour is learned by individual birds and can spread to others through social learning. In this chapter, multiple factors influencing the risk of cannibalism are reviewed. These include beak form, light intensity, genetic predisposition, age, sex, timing of sexual maturation, nutrition, food form, availability of attractive foraging materials, learning opportunities, availability of preferred victims, use of perches and nestboxes, and group size. Strategies for controlling cannibalism without resorting to beak trimming are suggested, based on knowledge about factors affecting the motivation and opportunity to perform the behaviour.

INTRODUCTION

Cannibalism is the act of consuming tissues of other members of the same species, whether living or dead and at any stage of the life cycle. This behaviour is widespread across the animal kingdom (Elgar and Crespi, 1992) and is a common problem in poultry (e.g. Cain *et al*., 1984; Sherwin *et al*., 1999), especially in domestic fowl of some layer strains. In laying hens, cannibalism may be directed towards different tissues, ranging from eggs to feathers (Lundberg and Keeling, 1999; McKeegan and Savory, 1999). However, this chapter will focus on the cannibalistic pecking and tearing of skin, underlying tissues and internal organs of living conspecifics, since it is this problem that raises the most serious concern from an animal welfare perspective.

Cannibalistic behaviour adversely affects the well-being of attacked birds, as evidenced by injuries which, if extensive, result in death. In hens with intact beaks, mortality due to cannibalism can affect over 30% of the flock (Allen and Perry, 1975; Curtis and Marsh, 1992; Craig and Muir, 1996).

At any age, cannibalistic pecks may be directed towards the toes or to feathered areas of the body and especially the tail. When directed towards feathered regions, cannibalism is correlated with severe feather pecking (Cloutier *et al*., 2000; see Rodenburg and Koene, this volume, Chapter 21, for classification of different forms of pecking). This may be because tail feathers start to bleed when

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broken during severe feather pecking and the blood then stimulates cannibalistic pecking. Accidental injuries resulting in bleeding may also stimulate cannibalism. Cloacal cannibalism (vent pecking), the most severe and fatal form of cannibalism, is rarely observed prior to the onset of lay. In cloacal cannibalism, pecks at the cloaca proceed to the removal and consumption of intestines and other internal organs, referred to as 'pick-out' in the poultry industry. In some cases, access to the internal organs is gained by pecking the abdomen rather than the cloaca (Yngvesson *et al.*, 2004).

In adult hens, a correlation between cloacal cannibalism and feather loss due to severe feather pecking has been found in some flocks (Craig, 1992; Pötzsch *et al.*, 2001) but not others (Gunnarsson *et al.*, 1999). Within a flock, different individuals may specialize in stereotyped gentle feather pecking, severe feather pecking or cannibalistic pecking (Keeling, 1994; R.C. Newberry *et al.*, unpublished). It appears that the same environmental conditions that trigger different forms of feather pecking can also trigger different forms of cannibalistic pecking, but the precise form and target of the pecking may vary with age and differ between individuals and flocks.

A difficulty in studying cannibalism in laying hens is that it is often not clear whether injurious pecking has lead to anything other than incidental ingestion of blood in the process of pecking, and the published literature rarely provides an indication of the extent of tissue consumption. Furthermore, when a bird is discovered in the process of being subjected to pecks by other flock members, and these pecks have broken the skin and precipitated bleeding, the only humane course of action is to remove the bird immediately from its attackers. Thus, one does not know whether the attack would have led to subsequent ingestion of tissues. For the purpose of this chapter, the term 'cannibalism' will, therefore, include incidences of injurious pecking that may or may not have led to true cannibalism if the bird had remained in the group.

Cannibalism is notoriously unpredictable. It has been reported in all types of housing system including cages, pens, aviaries and free-range systems (e.g. Swarbrick, 1986; Appleby *et al.*, 1988a; Cloutier *et al.*, 2000; Hovi *et al.*, 2003). In this chapter, multiple risk factors affecting the motivation and opportunity to perform cannibalism are discussed in an attempt to explain why outbreaks of cannibalism occur in some flocks but not others. Limitations of current methods of controlling cannibalism are presented, followed by suggestions for preventative measures based on an understanding of cannibalistic behaviour.

NEED FOR ALTERNATIVES TO BEAK TRIMMING TO CONTROL CANNIBALISM

In commercial practice, cannibalism is often controlled by beak trimming, involving removal of up to two two-thirds of the upper beak and less of the lower beak. Beak trimming reduces the incidence of beak-inflicted injuries (Blokhuis and Van Der Haar, 1989; Glatz, 1990), presumably because removal of the sharp hook of the upper beak mandible reduces the bird's ability to puncture and tear flesh. In addition, chronic pain resulting from the procedure (Breward and Gentle, 1985; Gentle *et al.*, 1990) may result in pecks being delivered in a less forceful manner, thereby making them less effective in causing tissue damage.

Moreover, beak trimming disrupts nociceptors and mechanoreceptors in the beak tip (Desserich *et al*., 1983; Gentle and Breward, 1986) which may reduce the effectiveness of cannibalistic pecking.

Beak trimming causes acute pain and, when performed after 10 days of age, may cause chronic pain due to neuromas (Breward and Gentle, 1985; Gentle *et al*., 1990, 1997; Glatz *et al*., 1992). Depending upon the timing and severity of the initial cut, there may be significant beak regrowth necessitating additional trimming at a later age to control cannibalism (Strong *et al*., 1983). Although beak trimming reduces the opportunity for birds to cause injuries to flock-mates, it does not eliminate the motivation to peck at other birds (Blokhuis and Van Der Haar, 1989). Furthermore, beak trimming does not entirely prevent cannibalism (Pötzsch *et al*., 2001) and is viewed by some as a mutilation. For these reasons, the practice is now banned or discouraged in several European countries and will not be permitted in England after 2010 (WOFA Regulations, 2002). In addition, major supermarket and restaurant customers are calling upon egg producers to find alternatives to beak trimming for the control of cannibalism.

Cannibalism has also been controlled by application of plastic devices that interfere with beak closure, thereby reducing the chance that pecks will cause damage. However, these devices have been associated with behavioural signs of discomfort and sometimes fall off (Savory and Hetherington, 1996). If cannibalism is to be controlled without resorting to beak trimming or mechanical devices that control the symptoms without addressing the underlying causes of this behaviour, improved knowledge about cannibalistic behaviour is needed.

NEED FOR ALTERNATIVES TO PERMANENTLY DIM LIGHTING TO CONTROL CANNIBALISM

Good visibility is necessary for the performance of cannibalistic behaviour. Cannibalism increases with increased light intensity (Hughes and Duncan, 1972; Kjaer and Vestergaard, 1999) and is commonly controlled by lowering the light intensity. Red lights have also been used to control cannibalism (Schumaier *et al*., 1968). Controlling cannibalism by rearing chicks in permanently dim or monochromatic lighting, or fitting hens with coloured contact lenses or goggles, is questionable because vision impairment has been associated with eye disorders, elevated mortality and reduced productivity (Robinson, 1979; Yinon, 1984; Adams, 1992). Moreover, if birds are kept in dim light, it is necessary to raise the light intensity for daily bird and equipment inspection, and this practice is associated with cannibalism (Pötzsch *et al*., 2001). Furthermore, cannibalism is a problem in free-range production (Hovi *et al*., 2003) where exposure to bright lighting is inevitable.

SELECT GENETIC STRAINS THAT ARE NOT CANNIBALISTIC

A promising alternative to beak trimming and dim lighting is to select against cannibalism in breeding programmes. The incidence of cannibalism varies between strains (Allen and Perry, 1975; Craig, 1992; Curtis and Marsh, 1992; Craig and Muir, 1996) and, using a group selection programme, Craig and Muir (1993) and

Muir (1996) have demonstrated that mortality due to beak-inflicted injuries is heritable. However, cannibalism is multifactorial and selection of hens that do not exhibit cannibalism could be achieved by many different mechanisms. For example, it is possible to select hens that are non-cannibalistic because they are blind and, thus, unable to express the behaviour (Ali and Cheng, 1985). To be able to assess the ethics of using a particular strain of non-cannibalistic hens, it is important to identify the mechanism(s) by which cannibalism is being controlled through genetic selection. In addition, given that behaviour results from the interaction between genotype and environment, it cannot be assumed that selection against cannibalism in one environment will produce a line that does not exhibit cannibalism in any environment. Control of the behaviour is likely to be most effective when utilizing relatively non-cannibalistic strains in combination with specific housing design features and husbandry techniques.

AVOID CONFUSING CANNIBALISM WITH SOCIAL AGGRESSION

In the poultry industry, cannibalism is often referred to as aggressive behaviour. Lumping cannibalism with social aggression may not be fruitful, given that the motivation underlying these two types of behaviour appears to be different. For example, Cloutier and Newberry (2002a) found that social aggression, involving pecks and threats directed towards the head, was elevated when groups of four unfamiliar hens were housed together, but there was no increase in injurious pecks directed towards other body parts. Furthermore, in flocks of several hundred hens, Odén *et al*. (1999) observed a reduction in aggression among the hens when housed with males, whereas male presence had no impact on the incidence of cloacal damage among the hens.

During a cannibalistic attack, there may be multiple cannibals, they are typically pecking from behind or to the side of the victim, the pecks are typically delivered in a foraging posture with the head and neck lowered, and the pecks incorporate tugging, tearing and swallowing components (Fig. 22.1). By contrast, in a dyadic aggressive interaction, the protagonists are typically facing each other and pecks are typically delivered while in an upright posture using a rapid, downward, stabbing motion. Social aggression may be a risk factor for cannibalism if beak-inflicted injuries occurring during aggressive behaviour result in bleeding that then stimulates cannibalism. However, given that cannibalistic and aggressive behaviour take different forms and occur in different contexts, it cannot be assumed that a reduction in social aggression will be accompanied by a reduction in cannibalism. In particular, beak-inflicted injuries of body parts other than the head are unlikely to be related to social aggression.

AVOID EARLY ONSET OF LAY

In flocks exhibiting cannibalism, a pronounced increase in mortality due to cannibalism typically starts around the time of sexual maturation. Allen and Perry (1975) observed that this mortality rose to a peak during the fourth month of lay and then declined. Newberry *et al*. (2002a,b) observed a rise in cannibalism directed to body parts other than the cloaca commencing prior to the onset of lay and coinciding

Fig. 22.1. Cloacal cannibalism.

with the timing of light stimulation. Cloacal cannibalism appeared at the onset of lay.

Whereas cannibalism in juveniles is performed by both by males and females, no reports were found of adult males engaging in cannibalism. This suggests that the rise in cannibalism in females associated with light stimulation is triggered by changes in female hormonal status. McKeegan and Savory (1998) observed an increase in plasma oestradiol to a peak around 16 weeks of age followed by a gradual decline to an intermediate level once egg laying was established. Plasma progesterone rose to a plateau at around 20 weeks of age, coinciding with an increase in feather pulling in some groups after the onset of lay. Hughes (1973) reported that the incidence of cannibalism was increased in juvenile pullets following implantation with exogenous oestradiol and progesterone whereas its appearance was delayed by testosterone implants. It is possible that elevated levels of oestradiol and progesterone during sexual maturation play a role in cannibalism through effects on food preferences (Alberti-Fidanza *et al.*, 1998; Clarke and Ossenkopp, 1998).

Pötzsch *et al.* (2001) reported that the incidence of cloacal cannibalism was positively correlated with onset of lay before 20 weeks of age. In agreement with this epidemiological finding, Newberry *et al.* (2002a,b) observed a high incidence of cloacal cannibalism that peaked early when using a photostimulation programme that resulted in early onset of lay (Lewis *et al.*, 1997). An altered pattern of gonadal steroid production, production of double-yolked eggs, physical immaturity, and laying of eggs on the floor rather than in nestboxes during early lay may contribute to cannibalism associated with early onset of lay (see below). Whatever the explanation, these results suggest that the risk of cannibalism can be reduced by using photostimulation programmes that delay the age at first egg until after 20 weeks of age.

MEET NUTRITIONAL REQUIREMENTS

Cannibalism has been positively correlated with nutritional deficiencies in poultry, including minerals, protein and energy (Cain *et al*., 1984; Cooke, 1992). Wahlström *et al*. (1998) reported cannibalism in hens fed a low-sodium diet. Blood has a salty flavour, which could explain an increased attraction to blood when fed a sodium-deficient diet, as found in pigs (Fraser, 1987). On the other hand, Hughes and Whitehead (1974) observed no increase in toe pecking when hens were provided with a sodium-deficient diet, and Hughes and Wood-Gush (1971) noted that NaCl solutions became increasingly aversive over time.

Ambrosen and Petersen (1997) reported that low-protein diets promoted cannibalism and feather loss in laying hens. In pigs, protein deficiency stimulated increased biting at blood-soaked tail models (Fraser *et al*., 1991), suggesting that cannibalism may be stimulated when there are inadequate levels of certain essential amino acids used in the synthesis of neurotransmitters and hormones affecting behaviour. Savory *et al*. (1999) reported a reduction in pecking damage in young bantams fed supplemental tryptophan, a precursor of serotonin and melatonin, possibly due to a sedative effect. Whether tryptophan supplementation would be effective in controlling cannibalism in adult hens without compromising productivity is unknown, but this strategy is unlikely to be economically feasible due to the high cost of tryptophan.

Mortality due to cannibalism did not differ in flocks fed diets containing 15.2% or more protein (Ambrosen and Petersen, 1997) or diets high versus low in methionine + cystine (Kjaer and Sørensen, 2002). McKeegan *et al*. (2001) found no difference in pecking damage between pullets fed plant-based diets versus diets including animal protein. Further, Yngvesson *et al*. (2004) found no difference in the feed intake or feed efficiency of cannibalistic hens compared with other hens from the same flock, suggesting that the cannibalistic hens were no more needy for nutrients than other hens in the flock. These studies suggest that manipulation of the nutrient content of feeds may be relatively ineffective in reducing cannibalism, providing that established daily nutritional requirements are met. Nevertheless, most of the published research on laying hen nutrition over the past 30 years has been conducted with beak-trimmed hens that are unable to express cannibalistic behaviour at a level sufficient for the detection of treatment differences. Additional research on the role of specific nutrients in cannibalism is warranted, taking into account individual, strain and age differences in response to nutrients.

PROVIDE ATTRACTIVE FORAGING MATERIALS

Rearing pullets without litter, or on litter types such as wood shavings that are relatively unattractive foraging substrates, increases the risk of feather pecking and cannibalism (Blokhuis and Van Der Haar, 1989; Hüber-Eicher and Wechsler, 1997). Even deprivation of litter for only the first 4 weeks after hatching can lead to elevated cannibalism in adulthood (Johnsen *et al*., 1998). A correlation found between cannibalism and the use of hanging drinkers (Pötzsch *et al*., 2001) could have resulted from wet litter conditions making the litter less attractive as a

foraging material. These findings are consistent with the hypothesis that pecking at flock-mates represents misdirected ground pecking behaviour that occurs in the absence of adequate ground pecking substrates (Blokhuis and Arkes, 1984).

Hüber-Eicher and Wechsler (1998) found that less cannibalism occurred when chicks were given long-cut straw bundled in sheaths rather than short-chopped straw, and polystyrene blocks rather than polystyrene beads. Furthermore, considerably less cannibalism occurred when hens were fed an unpelleted (mash) diet rather than a pelleted diet (Bearse *et al*., 1949), or pellets ground down into a mash (to control for changes in nutritive value associated with the pelleting process) rather than whole pellets (Newberry *et al*., 2002a). These results clearly demonstrate that the physical form in which feedstuffs and other foraging materials are presented affects cannibalistic behaviour independently of nutritional value. From these results, it follows that cannibalism in laying hens can develop when the available foraging materials do not fully satisfy a motivation to perform appetitive elements of foraging behaviour such as seeking, investigating and manipulating.

It appears that foraging materials must maintain sustained foraging activity to be effective in reducing cannibalism. Hartini *et al*. (2002) obtained lower mortality due to cannibalism in hens fed a diet high in insoluble fibre than in those fed a commercial diet, possibly because the birds spent longer feeding to meet their energy needs. Newberry *et al*. (2002a) observed no reduction in cannibalism among hens provided with lucerne hay cubes, which received relatively little attention from the birds, or small quantities of novel fruits and vegetables that were consumed very rapidly. By contrast, the regular feed that was available *ad libitum* sustained foraging activity longer when provided in ground rather than in whole pellet form (Newberry *et al*., 2002a), which may explain the effectiveness of the ground pellets in lowering the risk of cannibalism. In fact, when offered both forms of feed simultaneously, the hens ate more of the ground pellets than the whole pellets (Newberry *et al*., 2002a) even though it takes hens longer to consume an equivalent amount of feed in mash rather than pelleted form (Vilarino *et al*., 1996; Aerni *et al*., 2000).

The sustained attractiveness of ground pellets could be because they are more palatable than whole pellets and because they enable hens to investigate small particles of different food ingredients. Chickens are motivated to explore novel objects and food patches when fed *ad libitum* and presumably not seeking to meet an immediate dietary need (Newberry, 1999). Provision of foraging substrates that stimulate sustained foraging behaviour may, thus, satisfy an instrinsic need to explore, thereby helping to minimize pecking at other birds.

Dixon *et al*. (2003) found that a diet change from a preferred diet to a less preferred orange-flavoured diet stimulated exploratory pecking which could, potentially, be directed towards flock-mates. Phase feeding involves changes from nutrient-dense diets to more dilute diets as hens age. If the dilute diets are less preferred, this could explain why frequent diet changes were correlated with increased cloacal cannibalism in commercial flocks (Pötzsch *et al*., 2001). Dopamine has been implicated in the motivation to obtain preferred foods (Shimura *et al*., 2002; Volkow *et al*., 2002), suggesting that it may be involved in cannibalism. Support for this idea comes from observations of elevated blood dopamine levels in hens of a relatively cannibalistic strain (Cheng *et al*., 2001, 2002, 2003).

MINIMIZE OPPORTUNITIES TO LEARN CANNIBALISTIC BEHAVIOUR

If, in the course of exploratory pecking, birds break feathers or skin and bleeding ensues, the blood appears to stimulate further pecking, suggesting that it has reward value. Although pheasants and domestic chicks have been reported to show an initial aversion to dishes containing blood (Jones and Black, 1979; Jones and Faure, 1981, 1983), Yngvesson and Keeling (1998) reported that laying hens from cannibalistic flocks pecked more at bundles of blood-soaked, than plain, feathers. An initial attraction to the red colour of blood (in the absence of other reinforcing properties) seems unlikely, since Cloutier *et al*. (2000) found no difference in the rate of pecking at red- versus blue-dyed feathers. However, the degree of contrast between blood-stained feathers and the background colour of the plumage may affect the extent to which other birds notice a wounded bird. Further, once cannibalistic behaviour has become established within a flock, the colour and odour of blood may act as conditioned stimuli attracting cannibals to wounded birds.

Cloutier *et al*. (2002) observed that, after a period of habituation, pullets of a cannibalistic strain readily consumed chicken blood from open Petri dishes. Once they had made the association between a Petri dish and a blood reward, they were motivated to work to gain access to the blood by pecking holes through a cover placed over the Petri dish. Once learned, they performed this pecking behaviour to access the blood despite being fed a nutritionally complete diet *ad libitum*, suggesting that the behaviour was not motivated by hunger. Observations of contrafreeloading, in which animals work for food even though identical food is freely available (Inglis *et al*., 2001), suggest that the performance of the vigorous pecking behaviour required to obtain access to the blood, and the information gained from exposing the covered food source, may have been rewarding in themselves.

It has been observed that one death from cannibalism is often followed by more deaths in the same cage and, to a lesser extent, adjacent cages (Allen and Perry, 1975; Craig and Muir, 1993; Tablante *et al*., 2000). This outcome could be due to similarity of micro-environmental conditions in that region of the poultry house, such as relatively bright lighting. However, it is also possible that cannibalism can be spread through social learning, in which the birds acquire a new behaviour through observation of, or interaction with, other birds. Although some predisposing motivational factors may be common to different forms of cannibalism, individuals within a flock tend to specialize in a particular form of cannibalism, suggesting that birds pay attention to the specific body part that other birds are pecking and then learn to peck at that location for a food reward. The incidence of attacks to specific body parts varies between different flocks of the same strain kept under similar conditions (Allen and Perry, 1975; Newberry *et al*., 2002a,b), suggesting that birds may repeat the particular form of attack that they have learned rather than generalizing to other body parts.

Blood and tissue can be viewed as a novel food source for chickens that have not previously participated in cannibalism. Cannibalism also requires specific foraging behaviour to break skin and expose the underlying blood and tissue. Previous reports indicate that foraging on a novel food source is increased in naïve birds if they observe other birds foraging on the novel food (e.g. McQuoid and Galef, 1992; Nicol and Pope, 1994). Cloutier *et al*. (2002) established that a 'cannibalism' task requiring hens to peck and break a cover to gain access to chicken blood, which they then consumed, was learned individually by some birds

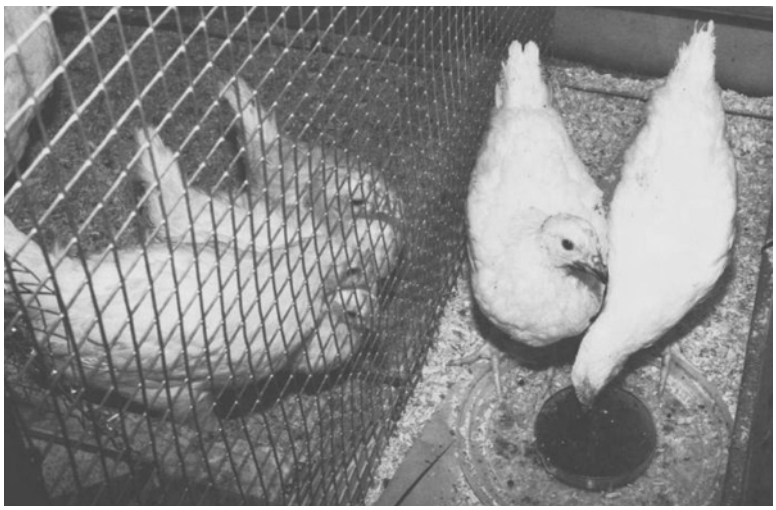

Fig. 22.2. Social learning of cannibalism.

(demonstrators) and then transmitted to others (naïve observers) through social learning. Social learning was more effective when the demonstrators performed the task in the same cage as the observers, but also occurred to a lesser degree when the observers were able to watch the demonstrators performing the task in an adjacent cage (Fig. 22.2). A combination of individual and social learning would, therefore, explain an escalating incidence and severity of cannibalism over time, and an increasing number of individuals found to be participating in cannibalistic attacks.

Once the behaviour has become well established, it may be very difficult to extinguish. Therefore, emphasis should be placed on minimizing opportunities for learning this behaviour. For example, housing should be designed in such a way that accidental bleeding injuries are avoided, and any injured or dead birds should be immediately removed from the flock. The effectiveness of applying tar or other anti-pecking compounds to wounds in preventing further pecking has not been studied systematically but frequent reapplication to maintain coverage may be impractical on a commercial basis. It may be beneficial to install visual barriers (Newberry and Shackleton, 1997; Sherwin *et al.*, 1999) between and within enclosures to limit spread of the behaviour through social learning. In addition, enrichment of the environment with novel objects and materials such as string (Jones *et al.*, 2002) may help to channel exploratory pecking in a harmless direction (see Jones, this volume, Chapter 20).

MINIMIZE THE AVAILABILITY OF ATTRACTIVE VICTIMS

Since cannibalism involves an interaction between the cannibal(s) and the victim, consideration should be given to characteristics of victims that may increase their probability of being attacked. It has been found that victims tend to have lower body weights than other birds in the flock and that they tend to be more bilaterally

asymmetric (Yngvesson and Keeling, 2001; Cloutier and Newberry, 2002b). Huon *et al*. (1986) reported a correlation between inadequate feeder space and cannibalism, which may have resulted from lack of uniformity of growth among the flock. In addition, McAdie and Keeling (2000) found that cannibalistic pecks were more likely to be directed towards birds with damaged feathers than towards those with intact plumage. Considering that cannibalism of diseased conspecifics has been reported in other avian species (see, e.g., Paullin, 1987), it is also possible that diseased hens attract cannibalistic pecks, which could explain a reported correlation between infections of the reproductive tract and pecks to the cloaca (Randall, 1977). Furthermore, feral fowl have been observed preying upon birds trapped in sticky vegetation (McBride *et al*., 1968), suggesting that birds that are disabled in some manner become attractive victims.

Thus, it appears that cannibals are attracted to victims that are less fit than other hens as a result of lower body weight, greater bilateral asymmetry, disease, bleeding injury, trapping or damaged plumage. From these findings, it follows that the risk of cannibalism will be lower in flocks with high body weight uniformity, body condition, health, bilateral symmetry and plumage quality. However, care must be taken to separate cause from effect, since cannibalistic attacks may also predispose surviving victims to subsequent infection and weight loss (although Yngvesson *et al*. (2004) did not detect these outcomes in a small sample of surviving victims).

The question also arises as to whether birds tend to prefer victims that appear different from themselves, or whether they peck at victims that appear different from the norm. When birds having different feather colour were housed together in equal numbers, Savory and Mann (1999) found that the most pecking was directed by light-coloured birds towards dark-coloured birds, whereas Chikamune *et al*. (1988) reported that birds with dominant white plumage received more pecking injuries than birds with barred plumage. It is difficult to interpret these results because plumage colour may not have been the only characteristic differing between the two types of birds. If hens respond to unusual appearance even of fit birds, then perhaps cannibalism could be reduced by rearing chicks in visually heterogeneous flocks so that they develop a broader interpretation of what constitutes the norm. Providing ultraviolet light that highlights individual markings that change over time has been reported to reduce pecking injuries in turkeys when accompanied by the provision of visual barriers, and straw as a foraging material (Lewis *et al*., 2000; Moinard *et al*., 2001).

In small flocks, McAdie and Keeling (2000) noted that birds that had been injured by cannibalistic pecking were sometimes re-attacked immediately upon return to their home-pen after healing, with cannibalistic pecks being directed towards the same location on the body that was previously injured. This might be because these birds retain subtle signs of their previous injury or because birds retain a memory of previous cannibalistic attacks. In either case, hens should be monitored closely when reintroducing them to a flock after recovery from a cannibalistic attack. It may be safer to return recovered birds to large, anonymous flocks than to small ones.

PROVIDE PERCHES AS REFUGES FROM AN EARLY AGE

Provision of perches reduces the risk of cannibalism, both during rearing and in adulthood (Fröhlich, 1991; Wechsler and Hüber-Eicher, 1998). Based on an

epidemiological study of cloacal cannibalism in Swedish aviaries, Gunnarsson *et al*. (1999) reported that access to perches by 4 weeks of age was correlated with a reduced risk of cloacal cannibalism in adult hens. Further, early access to perches (before 8 weeks of age) improved subsequent use of high perches in comparison with birds given perches only starting at 8 weeks of age (Gunnarsson *et al*., 2000). These findings suggest that there may be a sensitive period during which learning to manoeuvre in three dimensions is most effective.

Yngvesson *et al*. (2002) found that hens subjected to simulated cloacal pecking (using a water pistol) were more likely to take refuge on 40-cm-high perches if they had been reared with perches since hatching and were regularly roosting on perches before 12 weeks of age than if they had been reared without perches to 8 weeks of age and were still roosting on the floor at 12 weeks of age. Thus, it can be concluded that perches provide hens with an opportunity to avoid or escape cannibalistic attacks and that their effectiveness as refuges is increased if hens are reared with perches from an early age. Training to ensure perch use is also recommended.

More research is needed to determine an optimum layout of perches for reducing opportunities for cannibalism. Newberry *et al*. (2001) found that hens preferred the uppermost perches when given perches 20, 40 and 60 cm above the floor. Bilčík and Keeling (2000) noted that hens sitting on low perches (20 cm high) were feather pecked by hens on the floor, and Wechsler and Hüber-Eicher (1998) observed fewer incidents of severe feather pecking in flocks with perches 70 rather than 45 cm above the floor. Moinard *et al*. (1998) reported that more clocal cannibalism occurred in cages with a low perch than in cages without a perch. It appears that, to provide effective refuge against cannibalism, perches must be high enough to prevent birds on the floor from reaching up and pecking the perching birds. It seems unlikely that low perches in furnished cages would be as effective in enabling hens to avoid cannibals as the higher multi-tiered perches provided in non-cage systems.

To reduce the risk of cannibalism, housing should be designed in a manner that enables hens to avoid cannibals. A visually heterogeneous environment may assist hens in disappearing from attackers. Since hens seek safety on perches (simulating trees), shady areas among the perches may be beneficial, providing that alighting areas are illuminated sufficiently to avoid misjudged landings.

PROVIDE NESTS TO MINIMIZE VISIBILITY OF THE CLOACA DURING OVIPOSITION

Whereas cloacal cannibalism is directed towards hens, no reports were found in which males were victims of cloacal attacks. Direction of cannibalism specifically towards the cloaca of females may be due to attraction to the cloaca as a result of changes in its appearance at the onset of lay. It has been suggested that cannibalism may start when hens are attracted to everted mucosal tissue shortly following oviposition (Savory, 1995). In support of this idea, Hori and Kamei (1986) reported that, in two genetic strains of White Leghorn, the cloaca was everted for an average of 22 s and 44 s, respectively, following egg expulsion. Cloacal cannibalism was prevalent in the latter strain (Kawai *et al*., 1987). Although there may have been other strain differences that could account for this difference in

incidence of cannibalism, it appears that cloacal prolapse following oviposition can be a risk factor for cannibalism. In hens prone to prolapse, large egg size may be a further risk factor. If so, an association between cannibalism and early onset of lay (Pötzsch *et al*., 2001) may occur because hens stimulated to commence egg production at an early age produce more double-yolked eggs (Lewis *et al*., 1997).

Nevertheless, cloacal cannibalism can also occur in the absence of cloacal prolapse. Newberry *et al*. (2002a,b) observed no evidence of cloacal prolapse despite a high incidence of cloacal cannibalism. Yngvesson *et al*. (2004) observed no difference in the duration of oviposition between recovered victims and matched controls but observed that the egg was visible for seconds to minutes through the cloacal opening before expulsion of the egg. The cloaca was not visible after egg expulsion in these birds. Nor was there a correlation between the duration of oviposition and egg weight.

An egg in the process of emerging from the cloaca, surrounded by the highly vascularized cloacal tissue, may provide a powerful pecking stimulus. Pecking damage to the cloaca may lead to bleeding during subsequent ovipositions, thus attracting further pecking. Scabs resulting from cloacal pecking may also become a target for subsequent pecking at times other than at oviposition. Over time, cloacal pecking may intensify, leading to the discovery of palatable internal organs.

If reducing the visibility of the cloaca during oviposition reduces the risk of cloacal cannibalism, then providing nests and promoting their use by hens should be beneficial. It is suggested that individual nests will provide more privacy during oviposition than colony nests. In an epidemiological study, Pötzsch *et al*. (2001) reported that dimly lit nests were associated with more cloacal cannibalism than unlit nests. Providing nests that are enclosed and relatively dark rather than open or provided with supplementary lighting should, therefore, be beneficial.

It is also predicted that factors that increase nest use, including rearing with perches from an early age (Appleby *et al*., 1988b; Gunnarsson *et al*., 1999), will reduce oviposition in exposed locations, thereby reducing the risk of cloacal cannibalism. Given that there tends to be greater use of nests at the ends of rows rather than in the centre, promoting more even use of nestboxes may also be useful in reducing the chance that hens will witness oviposition by other hens or come into contact with their cloacas shortly after oviposition. For example, providing different coloured nests as landmarks, and preferred yellow nests in the centre of rows (Hüber-Eicher, 2003), may be helpful.

PROVIDE SUFFICIENT SPACE FOR ACCESS TO RESOURCES

In small groups of caged hens, increased cannibalism has been reported in groups of 6–8 birds in comparison with 3–4 birds (Hughes and Duncan, 1972; Allen and Perry, 1975; Newberry *et al*., 2002b), and elevated cannibalism in getaway cages has been attributed to the relatively large group sizes (>10 birds) in these cages (Appleby, 1998; Tauson, 1998). More cannibalism was also observed in flocks of 120 hens than in flocks of 15–60 hens (R.C. Newberry *et al*., unpublished). By contrast, no correlation was found between cloacal cannibalism and group size in aviary flocks ranging in size from 225 to 9954 hens (Gunnarsson *et al*., 1999), suggesting that there may be an upper limit to the group size effect.

Cannibalism may be more prevalent in large than small groups because:

1. There is an increased chance that the group will contain individuals genetically predisposed to cannibalism;
2. A cannibal has more potential victims in a larger group;
3. There is an increased chance of finding a preferred victim in a larger group;
4. There is less social inhibition of cannibalism due to a lower risk of retaliation;
5. There is an increased opportunity for spread of the behaviour by social learning.

Lefebvre and Giraldeau (1994) showed that, in pigeons, social learning was enhanced when the number of demonstrators increased.

Because flocks are larger in non-cage than in cage housing systems, there may be an increased risk of cannibalism in non-cage housing systems. However, this risk may be mitigated by other aspects of housing design. Perches, nests, tiers and other design features that divide the available space into physically or visually separated areas, and visual barriers between flocks, should be helpful in limiting cannibalism, although they make flock inspection by caretakers more difficult. Using hens that had not previously developed a strong cannibalism habit, Cloutier and Newberry (2002a) found that mixing unfamiliar hens of the same type did not increase the risk of cannibalism. This finding suggests that lack of individual recognition of flock-mates in large flocks is not a risk factor for cannibalism.

Despite the common belief that cannibalism results from overcrowding, experimental evidence for an impact of stocking density is limited. Møller *et al*. (1995) reported greater fluctuating asymmetry and body weight variation in chickens reared at higher stocking densities, which could increase the risk of cannibalism by increasing the availability of preferred victims. Hansen and Braastad (1994) reported higher mortality due to cannibalism in pullets reared in floor pens at a high versus low stocking density, but this could have been a group size effect since the different densities were achieved by manipulating group size. Increased stocking density was a risk factor for feather pecking damage in loose-housed pullets (Hüber-Eicher and Audige, 1999) and adult hens (Appleby *et al*., 1989), which could increase the risk of cannibalism directed at feathered body parts.

However, neither Carmichael *et al*. (1999) nor Gunnarsson *et al*. (1999) detected an effect of stocking density on cannibalism in large flocks of adult hens housed in percheries and aviaries. Although Nicol *et al*. (1999) observed more severe feather pecking near nestboxes than at other locations in percheries, especially at higher densities, vent pecking was rare and unaffected by density, possibly because most eggs were laid in enclosed nestboxes. In cages with litter of wood shavings and a low perch but without nestboxes, Newberry *et al*. (2002b) observed more cannibalism in hens housed at approximately 1000 versus 500 cm^2/hen. At these relatively high densities, the more crowded hens may have had a lower incidence of cannibalism due to general behavioural inhibition and because their cloacas were rarely visible due to other hens blocking the view. At lower densities (>1000 cm^2/hen), providing more space may reduce the risk of cannibalism if this facilitates the use of resources including feeders, drinkers, foraging materials, nestboxes and high perches.

CONCLUSIONS

Given the multifactorial nature of cannibalism, and the existence of genotype × environment interactions, further epidemiological data are needed from a range of commercial conditions, preferably from birds with intact beaks and good vision, so that the effects of housing conditions on cannibalism can be clearly detected. Additional controlled research and genetic selection against cannibalism are also needed, although this work is ethically and methodologically challenging. Improved understanding of the mechanisms underlying cannibalistic behaviour is needed to facilitate the development of humane strategies for controlling cannibalism in different housing systems.

In view of the Council of the European Union (1999) Directive to phase out the housing of laying hens in conventional battery cages by 2012, attention must be focused on factors affecting cannibalism in enriched cages and in large, loose-housed flocks. From the information reviewed above, it is recommended that hens be provided with nestboxes designed to minimize visibility of the cloaca during oviposition, perches that are high enough to provide refuge from birds on the floor, and sufficient space for ease of access to all resources. Access to perches, attractive foraging materials and feed in small-particle form should be provided throughout rearing as well as in the laying house. The age at first egg should be delayed until hens are at least 20 weeks old, and birds should be managed to minimize the availability of preferred victims and to prevent the discovery that flockmates represent a highly palatable food source.

REFERENCES

Adams, R.L. (1992) Effect of red plastic lenses on egg production, feed per dozen eggs, and mortality of laying hens. *Journal of Applied Poultry Research* 1, 212–220.

Aerni, V., El-Lethey, H. and Wechsler, B. (2000) Effect of foraging material and food form on feather pecking in laying hens. *British Poultry Science* 41, 16–21.

Alberti-Fidanza, A., Fruttini, D. and Servili, M. (1998) Gustatory and food habit changes during the menstrual cycle. *International Journal of Vitamin Nutrition Research* 68, 149–153.

Ali, A. and Cheng, K.M. (1985) Early egg production in genetically blind (rc/rc) chickens in comparison with sighted (Rc+/rc) controls. *Poultry Science* 64, 789–794.

Allen, J. and Perry, G.C. (1975) Feather pecking and cannibalism in a caged layer flock. *British Poultry Science* 16, 441–451.

Ambrosen, T. and Petersen, V.E. (1997) The influence of protein level in the diet on cannibalism and quality of plumage of layers. *Poultry Science* 76, 559–563.

Appleby, M.C. (1998) Modification of laying hen cages to improve behavior. *Poultry Science* 77, 1828–1832.

Appleby, M.C., Hogarth, G.S., Anderson, J.A., Hughes, B.O. and Whittemore, C.T. (1988a) Performance of a deep litter system for egg production. *British Poultry Science* 29, 735–751.

Appleby, M.C., Duncan, I.J.H. and McRae, H.E. (1988b) Perching and floor laying by domestic hens: experimental results and their commercial application. *British Poultry Science* 29, 351–357.

Appleby, M.C., Hughes, B.O. and Hogarth, G. (1989) Behaviour of laying hens in a deep litter house. *British Poultry Science* 30, 545–553.

Bearse, G.E., Berg, L.R., McClary, C.F. and Miller, V.L. (1949) The effect of pelleting chicken rations on the incidence of cannibalism. *Poultry Science* 28, 756.

Bilčík, B. and Keeling, L.J. (2000) Relationship between feather pecking and ground pecking in laying hens and the effect of group size. *Applied Animal Behaviour Science* 68, 55–66.

Blokhuis, H.J. and Arkes, J.G. (1984) Some observations on the development of feather-pecking in poultry. *Applied Animal Behaviour Science* 12, 145–157.

Blokhuis, H.J. and Van Der Haar, J.W. (1989) Effects of floor type during rearing and of beak trimming on ground pecking and feather pecking in laying hens. *Applied Animal Behaviour Science* 22, 359–369.

Breward, J. and Gentle, M.J. (1985) Neuroma formation and abnormal afferent nerve discharges after partial beak amputation (beak trimming) in poultry. *Experientia* 41, 1132–1134.

Cain, J.R., Weber, J.M., Lockamy, T.A. and Creger, C.R. (1984) Grower diets and bird density effects on growth and cannibalism in ring-necked pheasants. *Poultry Science* 63, 450–457.

Carmichael, N.L., Walker, A.W. and Hughes, B.O. (1999) Laying hens in large flocks in a perchery system: influence of stocking density on location, use of resources and behaviour. *British Poultry Science* 40, 165–176.

Cheng, H.W., Dillworth, G., Singleton, P., Chen, Y. and Muir, W.M. (2001) Effects of group selection for productivity and longevity on blood concentrations of serotonin, catecholamines, and corticosterone of laying hens. *Poultry Science* 80, 1278–1285.

Cheng, H.W., Singleton, P. and Muir, W.M. (2002) Social stress in laying hens: differential dopamine and corticosterone responses after intermingling different genetic strains of chickens. *Poultry Science* 81, 1265–1272.

Cheng, H.W., Singleton, P. and Muir, W.M. (2003) Social stress differentially regulates neuroendocrine responses in laying hens. I. Genetic basis of dopamine responses under three different social conditions. *Psychoneuroendocrinology* 28, 597–611.

Chikamune, T., Hoshino, T. and Ohguchi, O. (1988) Comparative studies on some quantitative traits between barred and dominant white chickens. 2. Cannibalism in growing chickens. *Japanese Poultry Science* 25, 41–44.

Clarke, S.N.D.A. and Ossenkopp, K.P. (1998) Hormone replacement modifies cholecystokinin-induced changes in sucrose palatability in ovariectomiezed rats. *Peptides* 19, 977–985.

Cloutier, S. and Newberry, R.C. (2002a) A note on aggression and cannibalism in laying hens following re-housing and re-grouping. *Applied Animal Behaviour Science* 76, 157–163.

Cloutier, S. and Newberry, R.C. (2002b) Differences in skeletal and ornamental traits between laying hen cannibals, victims and bystanders. *Applied Animal Behaviour Science* 77, 115–126.

Cloutier, S., Newberry, R.C., Forster, C.T. and Girsberger, K.M. (2000) Does pecking at inanimate stimuli predict cannibalistic behaviour in domestic fowl? *Applied Animal Behaviour Science* 66, 119–133.

Cloutier, S., Newberry, R.C., Honda, K. and Alldredge, J.R. (2002) Cannibalistic behaviour spread by social learning. *Animal Behaviour* 63, 1153–1162.

Cooke, B.C. (1992) Cannibalism in laying hens. *Veterinary Record* 131, 495.

Council of the European Union (1999) Council Directive 1999/74/EC of 19 July 1999 laying down minimum standards for the protection of laying hens. Annex Section 8. *Official Journal* L 203, 03/08/1999, pp. 0053–0057. Link to Document 31999L0074 available at: http://europa.eu.int/eur-lex/en/lif/reg/en_register_035030.html.

Craig, J.V. (1992) Beak trimming benefits vary among egg-strain pullets of different genetic stocks. *Poultry Science* 71, 2007–2013.

Craig, J.V. and Muir, W.M. (1993) Selection for reduction of beak-inflicted injuries among caged hens. *Poultry Science* 72, 411–420.

Craig, J.V. and Muir, W.M. (1996) Group selection for adaptation to multiple-hen cages: beak-related mortality, feathering, and body weight responses. *Poultry Science* 75, 294–302.

Curtis, P.E. and Marsh, N.W.A. (1992) Cannibalism in laying hens. *Veterinary Record* 131, 424.

Desserich, M., Ziswiler, V. and Fölsch, D.W. (1983) Die sensorische Versorgung des Hühnerschnabels. *Revue Suisse de Zoologie* 90, 799–807.

Dixon, G., Nicol, C. and Green, L. (2003) The effect of diet change on the behaviour of chicks. In: Ferrante, V. and the Scientific Committee (eds) *Proceedings of the 37th International Congress of the ISAE*. Fondazione Iniziative Zooprofilattiche e Zootecniche, Brescia, Italy, p. 204.

Elgar, M.A. and Crespi, B.J. (1992) *Cannibalism: Ecology and Evolution Among Diverse Taxa*. Oxford University Press, Oxford, UK.

Fröhlich, E.K.F. (1991) Zur Bedeutung erhöhter Sitzstangen und räumlicher Enge während der Aufzucht von Legehennen. *KTBL-Schrift* 344, 36–46.

Fraser, D. (1987) Mineral-deficient diets and the pig's attraction to blood: implications for tail biting. *Canadian Journal of Animal Science* 67, 909–918.

Fraser, D., Bernon, D.E. and Ball, R.O. (1991) Enhanced attraction to blood by pigs with inadequate dietary protein supplementation. *Canadian Journal of Animal Science* 71, 611–619.

Gentle, M.J. and Breward, J. (1986) The bill tip organ of the chicken (*Gallus gallus* var. *domesticus*). *Journal of Anatomy* 145, 79–85.

Gentle, M.J., Waddington, D., Hunter, L.N. and Jones, R.B. (1990) Behavioural evidence for persistent pain following partial beak amputation in chickens. *Applied Animal Behaviour Science* 27, 149–157.

Gentle, M.J., Hughes, B.O., Fox, A. and Waddington, D. (1997) Behavioural and anatomical consequences of two beak trimming methods in 1- and 10-day-old domestic chicks. *British Poultry Science* 38, 453–463.

Glatz, P.C. (1990) Effect of age of beak trimming on the production performance of hens. *Australian Journal of Experimental Agriculture* 30, 349–355.

Glatz, P.C., Murphy, L.B. and Preston, A.P. (1992) Analgesic therapy of beak-trimmed chickens. *Australian Veterinary Journal* 69, 18.

Gunnarsson, S., Keeling, L.J. and Svedberg, J. (1999) Effects of rearing factors on the prevalence of mislaid eggs, cloacal cannibalism and feather pecking in commercial flocks of loose housed laying hens. *British Poultry Science* 40, 12–18.

Gunnarsson, S., Yngvesson, J., Keeling, L.J. and Forkman, B. (2000) Rearing without early access to perches impairs the spatial skills of laying hens. *Applied Animal Behaviour Science* 67, 217–228.

Hansen, I. and Braastad, B.O. (1994) Effect of rearing density on pecking behaviour and plumage condition of laying hens in two types of aviary. *Applied Animal Behaviour Science* 40, 263–272.

Hartini, S., Choct, M., Hinch, G., Kocher, A. and Nolan, J.V. (2002) Effects of light intensity during rearing and beak trimming and dietary fiber sources on mortality, egg production, and performance of ISA brown laying hens. *Journal of Applied Poultry Research* 11, 104–110.

Hori, H. and Kamei, I. (1986) Research on time of contraction of the cloaca after oviposition. *Japanese Poultry Science* 23, 379–380.

Hovi, M., Sundrum, A. and Thamsborg, S.M. (2003) Animal health and welfare in organic livestock production in Europe: current state and future challenges. *Livestock Production Science* 80, 41–53.

Hüber-Eicher, B. (2003) The influence of colour on nest choice in laying hens. In: Ferrante, V. and the Scientific Committee (eds) *Proceedings of the 37th International Congress of the ISAE*. Fondazione Iniziative Zooprofilattiche e Zootecniche, Brescia, Italy, p. 62.

Hüber-Eicher, B. and Audige, L. (1999) Analysis of risk factors for the occurrence of feather pecking in laying hen growers. *British Poultry Science* 40, 599–604.

Hüber-Eicher, B. and Wechsler, B. (1997) Feather pecking in domestic chicks: its relation to dustbathing and foraging. *Animal Behaviour* 54, 757–768.

Hüber-Eicher, B. and Wechsler, B. (1998) The effect of quality and availability of foraging materials on feather pecking in laying hens chicks. *Animal Behaviour* 55, 861–873.

Hughes, B.O. (1973) The effect of implanted gonadal hormones on feather pecking and cannibalism in pullets. *British Poultry Science* 14, 341–348.

Hughes, B.O. and Duncan, I.J.H. (1972) The influence of strain and environmental factors upon feather pecking and cannibalism in fowls. *British Poultry Science* 13, 525–547.

Hughes, B.O. and Whitehead, C.C. (1974) Sodium deprivation, feather pecking and activity in laying hens. *British Poultry Science* 15, 435–439.

Hughes, B.O. and Wood-Gush, D.G.M. (1971) Investigations into specific appetites for sodium and thiamine in domestic fowl. *Physiology and Behavior* 6, 331–339.

Huon, F., Meunier-Salaun, M.C. and Faure, J.M. (1986) Feeder design and available feeding space influence the feeding behaviour of hens. *Applied Animal Behaviour Science* 15, 65–70.

Inglis, I.R., Langton, S., Forkman, B. and Lazarus, J. (2001) An information primacy model of exploratory and foraging behaviour. *Animal Behaviour* 62, 543–557.

Johnsen, P.F., Vestergaard, K.S. and Nørgaard-Nielsen, G. (1998) Influence of early rearing conditions on the development of feather pecking and cannibalism in domestic fowl. *Applied Animal Behaviour Science* 60, 25–41.

Jones, R.B. and Black, A.J. (1979) Behavioural responses of the domestic chick to blood. *Behaviour Neural Biology* 27, 319–329.

Jones, R.B. and Faure, J.M. (1981) The effects of age on the response of pheasants (*Phasianus colchicus*) to conspecific blood. *IRCS Medical Science* 9, 498–499.

Jones, R.B. and Faure, J.M. (1983) A further analysis of the responses of pheasants (*Phasianus colchicus*) to conspecific blood. *IRCS Medical Science* 11, 955–956.

Jones, R.B., McAdie, T.M., McCorquodale, C. and Keeling, L.J. (2002) Pecking at other birds and at string enrichment devices by adult laying hens. *British Poultry Science* 43, 337–343.

Kawai, M., Umeda, I., Sakurai, S. and Nakashima, Y. (1987) Observations on cannibalism induced by prolapse and its incidence in two commercial layer strains. *Japanese Poultry Science* 24, 316–319.

Keeling, L.J. (1994) Feather pecking: who in the group does it, how often and under what circumstances? In: *Proceedings of the 9th European Poultry Conference*, Glasgow, UK, pp. 288–289.

Kjaer, J.B. and Vestergaard, K.S. (1999) Development of feather pecking in relation to light intensity. *Applied Animal Behaviour Science* 62, 243–254.

Kjaer, J.B. and Sørensen, P. (2002) Feather pecking and cannibalism in free-range laying hens as affected by genotype, dietary level of methionine + cystine, light intensity during rearing and age at first access to the range area. *Applied Animal Behaviour Science* 76, 21–39.

Lefebvre, L. and Giraldeau, L.-A. (1994) Cultural transmission in pigeons is affected by the number of tutors and bystanders present. *Animal Behaviour* 47, 331–337.

Lewis, P.D., Perry, G.C. and Morris, T.R. (1997) Effect of size and timing of photoperiod increase on age at first egg and subsequent performance of two breeds of laying hen. *British Poultry Science* 38, 142–150.

Lewis, P.D., Perry, G.C., Sherwin, C.M. and Moinard, C. (2000) Effect of ultraviolet radiation on the performance of intact male turkeys. *Poultry Science* 79, 850–855.

Lundberg, A. and Keeling, L.J. (1999) The impact of social factors on nesting in laying hens (*Gallus gallus domesticus*). *Applied Animal Behaviour Science* 64, 57–69.

McAdie, T.M. and Keeling, L.J. (2000) Effect of manipulating feathers of laying hens on the incidence of feather pecking and cannibalism. *Applied Animal Behaviour Science* 68, 215–229.

McBride, G., Parer, I.P. and Foenander, F. (1968) The social behaviour and organization of feral domestic fowl. *Animal Behaviour Monograph* 2, 125–181.

McKeegan, D.E.F. and Savory, C.J. (1998) Behavioural and hormonal changes associated with sexual maturity in layer pullets. *British Poultry Science* 39 (Suppl.), S6–S7.

McKeegan, D.E.F. and Savory, C.J. (1999) Feather eating in layer pullets and its possible role in the aetiology of feather pecking damage. *Applied Animal Behaviour Science* 65, 73–85.

McKeegan, D.E.F., Savory, C.J., MacLeod, M.G. and Mitchell, M.A. (2001) Development of pecking damage in layer pullets in relation to dietary protein source. *British Poultry Science* 42, 33–42.

McQuoid, L.M. and Galef, B.G. Jr (1992) Social influences on feeding site selection by Burmese fowl (*Gallus gallus*). *Journal of Comparative Psychology* 106, 137–141.

Moinard, C., Morisse, J.P. and Faure, J.M. (1998) Effect of cage area, cage height and perches on feather condition, bone breakage and mortality of laying hens. *British Poultry Science* 39, 198–202.

Moinard, C., Lewis, P.D., Perry, G.C. and Sherwin, C.M. (2001) The effects of light intensity and light source on injuries due to pecking of male domestic turkeys (*Meleagris gallopavo*). *Animal Welfare* 10, 131–139.

Møller, A.P., Sanotra, G.S. and Vestergaard, K. (1995) Developmental stability in relation to population density and breed of chickens *Gallus gallus*. *Poultry Science* 74, 1761–1771.

Muir, W.M. (1996) Group selection for adaptation to multiple-hen cages: selection program and direct responses. *Poultry Science* 75, 447–458.

Newberry, R.C. (1999) Exploratory behaviour of young domestic fowl. *Applied Animal Behaviour Science* 63, 311–321.

Newberry, R.C. and Shackleton, D.M. (1997) Use of cover by domestic fowl: a Venetian blind effect? *Animal Behaviour* 54, 387–395.

Newberry, R.C., Estevez, I. and Keeling, L.J. (2001) Group size and perching behaviour in young domestic fowl. *Applied Animal Behaviour Science* 73, 117–129.

Newberry, R.C., Cloutier, S., Trudelle-Schwarz, R. and Ulibarri, C.M. (2002a) Effects of food form, hay cubes and novel foods on cannibalism in laying hens. In: *Proceedings of the Annual Meeting of the Poultry Science Association*, 12–15 August, 2002, Newark, Delaware.

Newberry, R.C., Cloutier, S. and Ulibarri, C.M. (2002b) Effects of group size and stocking density on cannibalism in laying hens. In: *Proceedings of the Annual Meeting of the Poultry Science Association*, 12–15 August, 2002, Newark, Delaware.

Nicol, C.J. and Pope, S.J. (1994) Social learning in small flocks of laying hens. *Animal Behaviour* 47, 1289–1296.

Nicol, C.J., Gregory, N.G., Knowles, T.G., Parkman, I.D. and Wilkins, L.J. (1999) Differential effects of increased stocking density, mediated by increased flock size, on feather pecking and aggression in laying hens. *Applied Animal Behaviour Science* 65, 137–152.

Odén, K., Vestergaard, K.S. and Algers, B. (1999) Agonistic behaviour and feather pecking in single-sexed and mixed groups of laying hens. *Applied Animal Behaviour Science* 62, 219–231.

Paullin, D.G. (1987) Cannibalism in American coots induced by severe spring weather and avian cholera. *Condor* 89, 442–443.

Pötzsch, C.J., Lewis, K., Nicol, C.J. and Green, L.E. (2001) A cross-sectional study of the prevalence of vent pecking in laying hens in alternative systems and its association with feather pecking, management and disease. *Applied Animal Behaviour Science* 74, 259–272.

Randall, C.J. (1977) A survey of mortality in 51 caged laying flocks. *Avian Pathology* 6, 149–170.

Robinson, D. (1979) Effects of cage shape, colony size, floor area and cannibalism preventatives on laying performance. *British Poultry Science* 20, 345–356.

Savory, C.J. (1995) Feather pecking and cannibalism. *World's Poultry Science Journal* 51, 215–219.

Savory, C.J. and Hetherington, J.D. (1996) Would plastic anti-pecking devices be an acceptable alternative to beak trimming for controlling pecking problems in laying hens? *British Poultry Science* 37, S25–S26.

Savory, C.J. and Mann, J.S. (1999) Feather pecking in groups of growing bantams in relation to floor litter substrate and plumage colour. *British Poultry Science* 40, 565–572.

Savory, C.J., Mann, J.S. and Macleod, M.G. (1999) Incidence of pecking damage in growing bantams in relation to food form, group size, stocking density, dietary tryptophan concentration and dietary protein source. *British Poultry Science* 40, 579–584.

Schumaier, G., Harrison, P.C. and McGinnis, J. (1968) Effect of colored fluorescent light on growth, cannibalism, and subsequent egg production of single comb White Leghorn pullets. *Poultry Science* 47, 1599–1602.

Sherwin, C.M., Lewis, P.D. and Perry, G.C. (1999) Effects of environmental enrichment, fluorescent and intermittent lighting on injurious pecking amongst male turkey poults. *British Poultry Science* 40, 592–598.

Shimura, T., Kamada, Y. and Yamomoto, T. (2002) Ventral tegmental lesions reduce overconsumption of normally preferred taste fluid in rats. *Behavioral Brain Research* 134, 123.

Strong, C.F., Reynnells, R.D., Benoff, F.H. and Mauldin, J.M. (1983) Pullet beak trimming requires special care. *Poultry Digest* 42, 374–378.

Swarbrick, O. (1986) Clinical problems in 'free range' layers. *Veterinary Record* 118, 363.

Tablante, N.L., Vaillancourt, J.-P., Martin, S.W., Shoukri, M. and Estevez, I. (2000) Spatial distribution of cannibalism mortalities in commercial laying hens. *Poultry Science* 79, 705–708.

Tauson, R. (1998) Health and production in improved cage designs. *Poultry Science* 77, 1820–1827.

Vilarino, M., Picard, M.L., Melcion, J.P. and Faure, J.M. (1996) Behavioural adaptation of laying hens to dilution of diets under mash and pellet form. *British Poultry Science* 37, 895–907.

Volkow, N.D., Wang, G.-W., Fowler, J.S., Logan, J., Jayne, M., Franceschi, D., Wong, C., Gatley, S.J., Gifford, A.N., Ding, Y.-S. and Pappas, N. (2002) 'Non-hedonic' food motivation in humans involves dopamine in the dorsal striatum and methylphenidate amplifies this effect. *Synapse* 44, 175–180.

Wahlström, A., Tauson, R. and Elwinger, K. (1998) Effects on plumage condition, health and mortality of dietary oats/wheat ratios to three hybrids of laying hens in different housing systems. *Acta Agriculturae Scandinavica* 48, 250–259.

Wechsler, B. and Hüber-Eicher, B. (1998) The effect of foraging material and perch height on feather pecking and feather damage in laying hens. *Applied Animal Behaviour Science* 58, 131–141.

WOFA Regulations (2002) *Statutory Instrument 2002 No. 1646. Welfare of Farmed Animals (England) (Amendment) Regulations 2002*. Queen's Printer of Acts of Parliament. Web publication at http://www.legislation.hmso.gov.uk/si/si2002/20021646.htm.

Yinon, U. (1984) Myopia induction in animals following alteration of the visual input during development, a review. *Current Eye Research* 3, 677–690.

Yngvesson, J. and Keeling, L.J. (1998) Are cannibalistic laying hens more attracted to blood in a test situation than other hens? In: Veissier, I. and Boissy, A. (eds) *Proceedings of the 32nd International Congress of the ISAE*. INRA, Clermont-Ferrand, France, p. 173.

Yngvesson, J. and Keeling, L.J. (2001) Body size and fluctuating asymmetry in relation to cannibalistic behaviour in laying hens. *Animal Behaviour* 61, 609–615.

Yngvesson, J., Nedergård, L. and Keeling, L.J. (2002) Cannibalism in laying hens: effect of early access to perches on escape behaviour. In: Koene, P. and the Scientific Committee (eds) *Proceedings of the 36th International Congress of the ISAE*. P. Koene for the Organising Committee, Wageningen, The Netherlands, p. 81.

Yngvesson, J., Keeling, L.J. and Newberry, R.C. (2004) Individual production differences do not explain cannibalistic behaviour in laying hens. *British Poultry Science* 45 (in press).

CHAPTER 23
Skeletal disorders in laying hens: the problem of osteoporosis and bone fractures

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ABSTRACT

Osteoporosis is the major factor predisposing laying hens to the severe welfare problem of bone fractures. It arises from a generalized loss of structural bone throughout the skeleton that starts when the hens begin to mature sexually and continues throughout the period of continuing egg production, resulting in progressively weaker bones and increasing fracture risk. When hens go out of lay, structural bone regeneration can recommence and the effects of osteoporosis can be reversed. The severity of osteoporosis is increased in hens kept in battery cages, when inactivity contributes to bone loss. The weakened bones in end-of-lay battery hens result in a high proportion of fractures, particularly in wing, keel and leg bones, occurring during depopulation.

The origins of osteoporosis are mainly cellular, but nutrition has a role in helping to counter the condition, firstly by preventing deficiency, which can make the problem worse, and secondly, by promoting good nutrient supply. Provision of a particulate source of calcium is particularly helpful.

Keeping birds in alternative husbandry systems that allow them more opportunity for exercise can markedly decrease the severity of osteoporosis. Bones will strengthen in response to the biochemical forces applied to them. However, hens can still experience high incidences of fractures that occur mainly during their lifetimes within the systems. Although their bones may be stronger, the hens have greater opportunities for more traumatic accidents that can still result in bone fractures. A particular problem of damage to keel bones is associated with misjudged landings on perches. Thus, replacing battery cages with furnished cages or more extensive systems such as aviaries does not necessarily improve the skeletal welfare of hens.

Bone quality has been found to have a strong genetic component. A divergent selection programme based upon retrospective selection of progeny on the basis of postmortem maternal bone characteristics has resulted in the formation of two lines that show a twofold difference in bone strength after seven generations of selection. The greater bone strength has been shown to result in fewer fractures. The improvement in bone quality in the strong bone line is accounted for by more bone formation during rearing and much less structural bone resorption during the laying period. The latter effect may be related to better protection of structural bone surfaces by more medullary bone and lower osteoclast number resulting in less bone resorption. Egg production in the two lines is similar, though the strong bone line has slightly poorer

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eggshell quality. The birds have been selected in cages, but the same improvements in bone strength were seen when the lines were housed in an aviary. The development of more efficient *in vivo* methods for predicting bone quality, perhaps based on genetic markers, will allow selection for better bones to be applied in commercial breeding programmes. Application of this genetic approach should help to solve the problem of bone fractures in laying hens, in whatever husbandry system the birds are kept.

INTRODUCTION

Bone fractures are the most serious type of skeletal problems in modern laying hens. They occur in response to trauma in hens in all laying systems, where the fragility of the bones may predispose them to fracture. Osteoporosis has been identified as the main factor causing bone fragility in hens and is defined as a decrease in the amount of fully mineralized structural bone, leading to increased susceptibility to fracture. It contrasts with another cause of bone mineral loss, osteomalacia, where there is defective mineralization of bone tissue, with thick seams of poorly mineralized organic matrix. Both conditions will lead to poor quality bone but, whereas osteomalacia is primarily associated with nutritional deficiencies of calcium, phosphorus or vitamin D, osteoporosis is an altogether more complex problem.

A condition involving bone loss characteristic of osteoporosis was first described in caged laying hens by Couch (1955) who reported a problem termed 'cage layer fatigue' involving bone brittleness, paralysis and death. More recently, confirmation of osteoporosis as the main reason for bone loss and subsequent fractures in laying hens has been provided (Randall and Duff, 1988). The consequences of osteoporosis for the laying hen skeleton can be severe. Caged layer fatigue seems to be an extreme consequence of loss of structural bone in the vertebrae that leads to spinal bone collapse and paralysis (Urist and Deutsch, 1960; Bell and Siller, 1962). Generally, however, osteoporosis is not so severe as to result in caged layer fatigue but nevertheless the widespread structural bone loss can lead to high incidences of fractures at various sites throughout the skeleton.

Gregory and Wilkins (1989) reported the results of a survey of end-of-lay battery hens in the UK in which 29% of hens had one or more broken bones during their lifetimes. The fractures occurred during their time in their cages or during depopulation, transport to a processing factory and hanging on shackles. Astonishingly, 98% of carcasses were found to contain broken bones by the time they reached the end of the evisceration line. A subsequent survey of a number of European flocks confirmed these findings, showing that, on average, fractures were received by 10% of hens during their time in batteries and a further 17% during depopulation and transport (Gregory *et al.*, 1994). The high fracture incidences show that osteoporosis constitutes a severe welfare problem in hens. Production losses and mortality also arise with caged layer fatigue. These economic losses are compounded by the high fracture incidences during carcass processing which lead to bone splinters in recovered meat and have resulted in processors becoming unwilling to handle spent layers (Brown, 1993).

The origins of osteoporosis are not well defined. It has been suggested that the problem is partly genetic in origin, resulting from the breeding of lightweight, energetically efficient birds that maintain a high rate of lay over a prolonged period

(Whitehead and Wilson, 1992). Most modern hybrid layer strains seem to be susceptible to osteoporosis, but older unimproved strains, such as the Roslin J-line Brown Leghorn, are relatively resistant (Rennie *et al.*, 1997). However, even in susceptible strains there can be wide individual variation, with some hens retaining good bone quality at end of lay. Confining birds in cages with limited opportunity for exercise has undoubtedly contributed to the problem, resulting in a form of disuse osteoporosis. The characteristics of osteoporosis and the various factors influencing it are described in the following sections.

CHARACTERISTICS OF OSTEOPOROSIS

Bone Types and Turnover

Bone is made up of hydroxyapatite crystals of calcium phosphate deposited on an organic collagen matrix. There are several different bone types in laying hens. The main types providing structural integrity are cortical and cancellous (or trabecular) bone, both of which are forms of lamellar bone. These bone types are formed during growth, but when a hen reaches sexual maturity, a third type of non-structural bone, medullary bone, is formed. After formation, bone undergoes a constant process of remodelling, in which osteoclast cells resorb areas of bone and are then replaced by osteoblasts which deposit new bone. Osteoporosis arises where there is an imbalance between these processes, resulting in a net resorption of structural bone.

Medullary bone is a woven bone whose purpose is to provide a labile source of calcium for shell formation. It is characterized by the haphazard organization of collagen fibres in its matrix, and is mechanically weaker than the structural bone types. It occurs as nodules or spicules within the marrow cavity and as a layer lining the surfaces of structural bone components, as shown in Fig. 23.1a. The highest content of medullary bone is usually found in the leg bones. The mineral density of medullary bone is usually similar to that of cancellous bone, so measures of radiological density or ash content in these bones give little information relevant to osteoporosis.

The conventional view that medullary bone contributes little to overall bone strength may not be totally correct. The layer of medullary bone may sustain the connectivity of trabecular bone during osteoporosis, as shown in Fig. 23.1a, and the nodules may increase fracture resistance. More direct evidence comes from observations on the humerus. This bone is usually pneumatized as a genetic adaptation to flight. However, variable proportions of hens in different flocks can have non-pneumatized humeri that can contain marrow and medullary bone (as shown in Fig. 23.2) for reasons that are unknown. The amount of medullary bone varies from a partial filling around the periphery of the cortical cavity to complete filling of the cavity. Measures of humeral bone three-point breaking strength have shown that these are highly correlated with the amount of humeral medullary bone present (Fleming *et al.*, 1998a). Medullary bone may thus make some contribution to the overall fracture resistance of bone, though not to the same degree as structural bone.

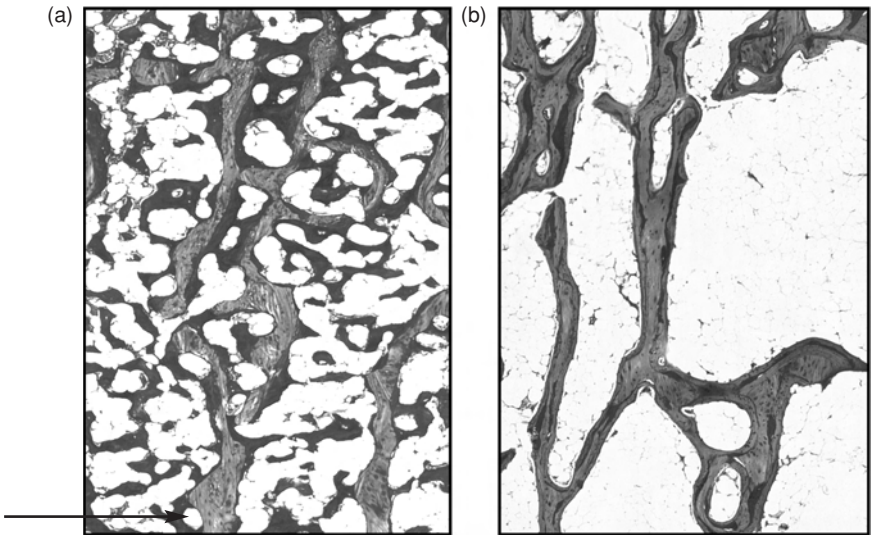

Fig. 23.1. Histological sections of bones of hens in lay and out of lay. (a) Hen in lay, showing trabecular bone (grey) and medullary bone (black) in nodules between the trabeculae and coating the surfaces of trabeculae. Medullary bone assisting trabecular connectivity is arrowed. In the out-of-lay hen (b), medullary bone has largely been resorbed and a new layer of trabecular bone has been deposited on top of the previous lining layer of medullary bone.

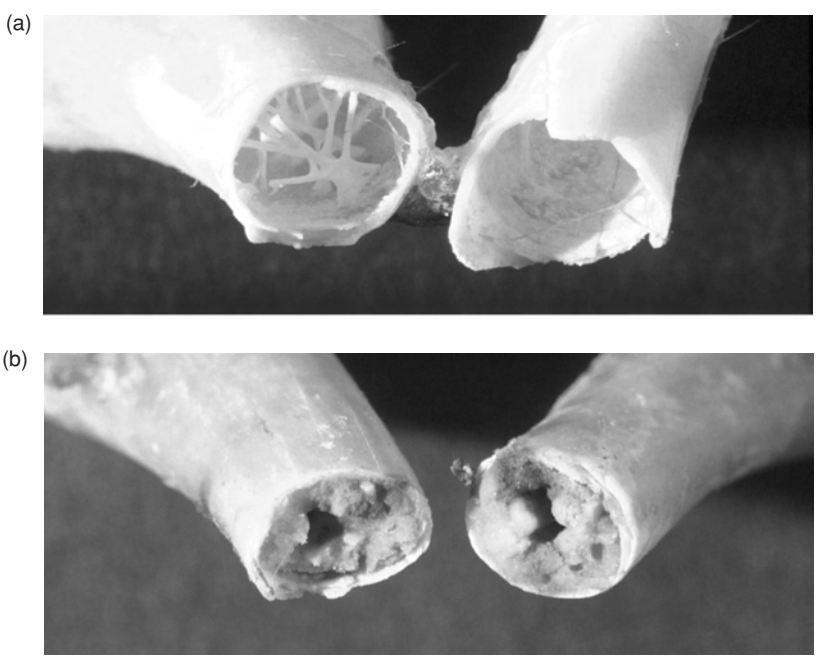

Fig. 23.2. Humerus of laying hen showing (a) normal pneumatized internal cavity and (b) cavity almost completely filled with medullary bone.

Development of Osteoporosis

Some of the characteristics of laying hen osteoporosis have been reviewed by Whitehead and Wilson (1992). Osteoporotic hens show evidence of widespread loss of structural bone throughout the skeleton. This loss has been shown to start when hens reach sexual maturity and to continue throughout the laying period (Wilson *et al*., 1992) so that osteoporosis is most severe in hens at the end of lay. The observations are consistent with the theory that at the onset of sexual maturity the rise in circulating oestrogen results in a switch in bone formation from structural to medullary bone and that continued resorption of structural bone leads to osteoporosis. Osteoblast activity is regulated by oestrogen and it is likely that the oestrogen surge at sexual maturity stimulates formation of woven rather than lamellar bone. Evidence for a depression in structural bone formation in laying hens has been provided by Hudson *et al*. (1993), who observed that fluorochrome label was not incorporated into cortical bone. These findings have been confirmed by R.H. Fleming (unpublished) who also observed that loss of reproductive condition induced by forced moulting resulted in rapid loss of medullary bone and resumption of structural bone formation (Fig. 23.1b).

As osteoporosis progresses, cortical bone thickness is decreased and there is a less cohesive system of fewer, thinner and less well connected trabeculae. This is reflected in lower breaking strengths, as measured by the three-point bending test. Amounts of structural bone can also be quantified by computerized histomorphometric analysis, or by radiography for bones that contain little or no medullary bone. Other measures that have been made to assess osteoporosis include cancellous bone volumes of the free thoracic vertebra (FTV) and proximal tarsometatarsus (PTM), radiographic densities of humerus and keel and breaking strengths of humerus and tibia. Whitehead and Wilson (1992) proposed a system for assessing the severity of osteoporosis based on FTV trabecular bone volume, with values above 16% being normal, 14–16% moderate, 8–11% severe and <8% very severe.

Patterns of bone loss with age have been found to vary between different bones (Fleming *et al*., 1998b). Striking changes occur during the first 10 weeks of sexual maturity. There is a marked loss of cancellous bone in both the PTM and FTV, suggesting that, in these bones, the major development of osteoporosis occurs within a few weeks of the onset of egg production. Over this period there is also a rapid accumulation of medullary bone in the PTM but at present there is no indication as to whether the loss of cancellous bone is directly linked to the formation of medullary bone. After 25 weeks the further loss of cancellous bone from the FTV is smaller, but loss of cancellous bone and the accumulation of medullary bone continue in the PTM, although also at reduced rates. However, there is a continuous net increase in the total amount of bone, measured histomorphometrically, with the result that total bone volume in the PTM can be greatest at 70 weeks.

Radiographic density can be taken as an indirect measure of the total amount of bone material. In the FTV, radiographic density has been observed to increase between 15 and 25 weeks whilst cancellous bone volume decreases. Though relatively small amounts of medullary bone form in the central parts of the FTV, this increase in density can perhaps be accounted for by accumulation of medullary bone in the subchondral area. Subsequent decreases in radiographic density would be consistent with the small decline in cancellous bone volume.

Tibial radiographic densities and breaking strengths, both measured in the midshaft region, were found to increase over the period 15–25 weeks. The laying hen tibia is known to contain appreciable amounts of medullary bone and the increase in radiographic density would be consistent with this occurrence. The small increase in tibial breaking strength between 15 and 25 weeks could thus indicate some accumulation of medullary bone but relatively little loss of structural bone. The major decrease in bone strength between 25 and 50 weeks implies considerable loss of structural bone, which in the midshaft region of the tibia is mainly cortical bone. These observations contrast with the findings in the PTM that major structural bone loss occurs within 10 weeks of sexual maturity and suggest that different principles may apply to structural bone resorption from epiphyseal and midshaft regions of leg bones. An important factor in this difference may be the greater resorptive surface areas of bone contained in the trabecular structures in epiphyseal regions than in the diaphyseal cortex.

The increases in humerus radiographic density and breaking strength observed between 15 and 25 weeks may be accounted for by the development in some birds of medullary bone in bones that are normally pneumatized, together with the absence of any appreciable loss of structural bone over this period. The subsequent large decline in breaking strength after 25 weeks would suggest that in this bone, as in the tibia, the major onset of osteoporosis occurs at a later age than for the PTM or FTV.

The radiographic density of the keel can also decline, particularly at the leading edge of this bone adjacent to the rest of the sternum. A more general increase in keel radiographic density seen later in the laying period is consistent with the known presence of medullary bone and does not give any insight into possible changes with time in the structural component.

Though most of the characteristics of osteoporosis can be attributed to loss of mineralized structural bone, the possible contribution of changes in the collagenous matrix of bone cannot be ignored. Knott *et al*. (1995) compared collagen structure in normal and osteoporotic hen bones and found a decrease in pyrrolic crosslinks in the latter. This could contribute to overall bone weakness. In hens selected for better bone strength, an increase in crosslinking, particularly pyrrolic crosslinking, in the collagen matrix was thought to contribute partly to the better bone quality (Sparke *et al*., 2002).

Consequences of Osteoporosis

The decline in structural cortical and trabecular bone components does not cause changes in the external dimensions of long bones because cortical bone resorption is confined to endosteal surfaces. However, the thinning of cortical bone and loss of trabecular integrity results in bones becoming weaker and more susceptible to fracture if subject to trauma. Ischium, humerus, keel and furculum showed the highest fracture incidences, with pubis, ulna, coracoid and femur also breaking frequently (Gregory and Wilkins, 1989). Different fractures can occur at different stages in a bird's life. In a survey of European flocks, Gregory *et al*. (1994) reported that 17% of birds experienced fractures during battery cage life (old breaks) and 10% during depopulation, transport and hanging on shackles (new breaks). Fractures to the humerus and ulna are frequent old breaks. Damage to the

Fig. 23.3. Radiograph of the wing of a laying hen showing a spiral fracture in the humerus. A fracture callus has formed and started the healing process.

keel can arise from contact with the cage front during depopulation and femur breaks commonly arise during shackling.

Fractures of the humerus are usually of the spiral type, as shown in Fig. 23.3, suggesting torsional forces arising from violent contact with the cage. These fractures usually repair, with the fracture callus able to unite quite widely displaced bone surfaces. Fractures of the keel occur at the point of bone erosion at the front edge shown in Fig. 23.4 and result in the bone bending over along the line of the keel. Attempts at repair result in new bone growth in the original direction of the

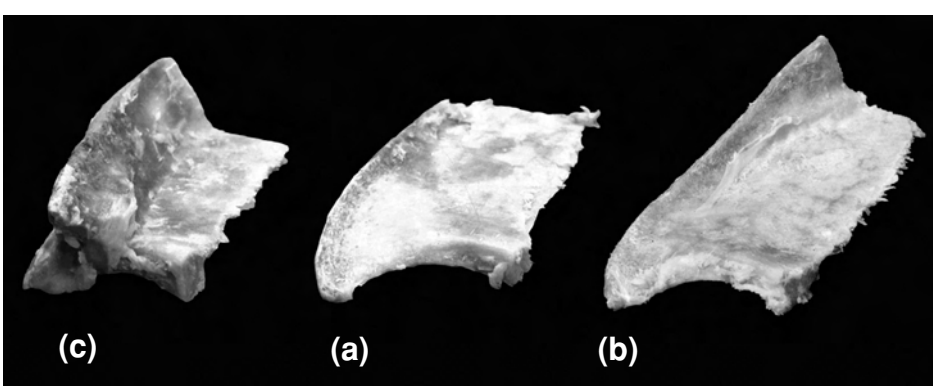

Fig. 23.4. Excised keels showing (a) normal appearance, (b) 'twisted' keel, and (c) keel with a severe deformity.

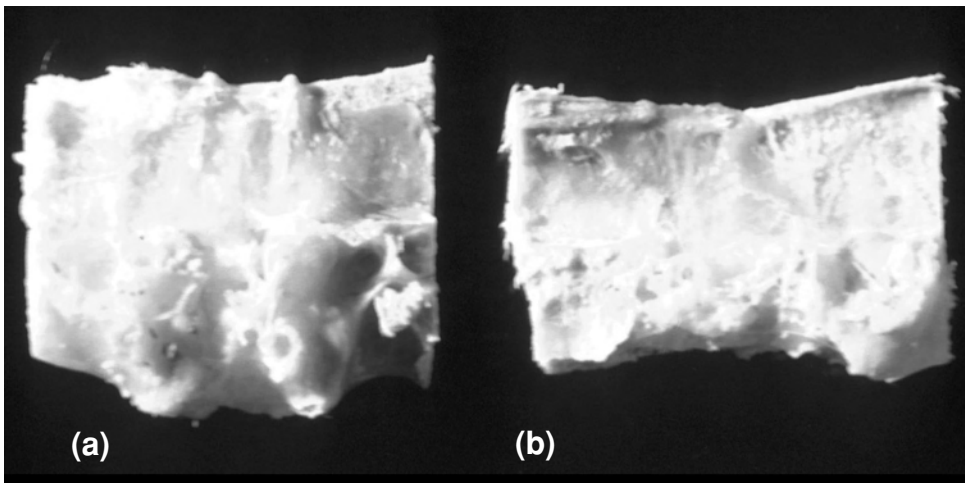

Fig. 23.5. Vertebrae from (a) normal and (b) osteoporotic hen, showing severe bone loss.

keel and can result in a characteristic deformity. These repairs to different bones involve the initial formation of fracture callus followed by structural bone and show that local factors can override the more general suppression of structural bone formation during lay.

Spinal bones can be severely affected by osteoporosis, but fractures are rarely observed. Instead, the loss of trabecular and cortical bone (Fig. 23.5) can lead to exposure of the spinal column and it is presumed that pressure on exposed nerves accounts for the paralysis seen in caged layer fatigue. These lesions may also repair because provision of extra calcium can result in recovery, though this recovery may also be assisted by a temporary loss of reproductive condition.

The welfare problem of osteoporosis is generally assessed in relation to fracture incidence. Avian bones are enervated and it is assumed from human analogy that avian fractures are also painful. However, it is possible that pain may also arise in the absence of overt fracture from compression of the skeleton and entrapment of nerves.

EFFECTS OF EXERCISE AND HUSBANDRY SYSTEM

Effects on Bone Characteristics

The effects of load-bearing and biomechanical forces in stimulating bone formation and remodelling are well established (Lanyon, 1992). Induced inactivity has been shown to accelerate osteoporosis in birds (Nightingale *et al.*, 1972) and the relative lack of activity of battery caged hens accounts for the severity of the problem in these birds. Effects of exercise and alternative housing systems have been widely studied as potential means of alleviating osteoporosis.

The effects of exercise as a way of stimulating bone growth during rearing have been studied, but neither housing birds in pens nor giving extra exercise

through the use of a carousel have improved bone quality at start of lay in cage-reared birds (Whitehead and Wilson, 1992).

Changes in bone quality during the laying period are influenced by the nature of the exercise involved. Housing hens in pens has resulted in little change in spinal trabecular bone (Wilson *et al*., 1993). This suggests that merely allowing the birds more opportunity to walk does not result in generalized bone improvements, although the limited nature of the observations did not preclude the possibility of more local benefits, such as in leg bones. Fitting perches to cages resulted in small improvements in PTM trabecular bone volume, but no benefit in tibia strength (Hughes *et al*., 1993). More vigorous exercise than is obtained by walking or hopping on to low perches is needed to markedly improve bone quality. This was demonstrated by Knowles and Broom (1990), who found superior tibia and humerus breaking strengths in birds housed in terrace or perchery systems rather than in cages. The improvement in humerus strength was particularly apparent in the perchery system, which allowed birds to fly. Norgaard-Nielsen (1990) also reported better bone strength in hens housed in alternative systems to battery cages.

Confirmation of these findings came from a more detailed study by Fleming *et al*. (1994) involving the comparison of battery cages with three different aviary systems. Considerable improvements in a wide range of bone morphometric and strength characteristics were observed in birds housed in aviaries, as shown in Table 23.1, with the greatest improvement being in the strength of the humerus. The improvements in the strength of this bone were more pronounced in the perchery, which was tiered with many high perches, compared with the litter and wire system which had only relatively low perches. Thus opportunity for flight was an important factor in improving humerus strength. These findings in hens are consistent with findings in other species that biomechanical effects on individual bones are dependent upon the degree of strain experienced by the bone.

Table 23.1. Bone characteristics in end-of-lay hens housed in different husbandry systems.

	Husbandry system		
Trait	Battery cage	Litter and wire	Perchery
Proximal tarsometatarsus			
Cancellous bone volume (%)	14.2a	16.7b	16.8b
Free thoracic vertebra			
Cancellous bone volume (%)	11.3a	13.6b	16.6c
Tibia			
Breaking strength (kg)	21.8a	25.7b	28.6b
Radiographic density (mm Al equivalent)	2.95a	3.48b	3.33b
Humerus			
Breaking strength (kg)	13.1a	22.6b	25.4c
Cortical width (mm)	0.51a	0.67b	0.72b
Radiographic density (mm Al equivalent)	0.75a	1.11b	1.25c

Within a row, values followed by a different letter differ significantly ($P<0.05$) (Fleming *et al*., 1994).

There is little information on the mechanism by which exercise improves bone characteristics in the hen. Newman and Leeson (1998) reported that tibial strength increased within 20 days of transferring end-of-lay hens from cages to an aviary. This finding suggests that the mechanism may involve some stimulation of structural bone formation, though the possibility cannot be excluded that the increase in bone thickness might have been associated with some temporary loss of egg production in hens transferred to a radically different environment.

Welfare of Hens in Different Housing Systems

There have been several studies to determine the welfare impact of the improved bone strength of birds kept in alternative housing systems. Lower incidences of new breaks have been found in birds depopulated from aviary or free-range systems compared with battery cages (Gregory *et al.*, 1990; van Niekerk and Reuvekamp, 1994). However, the incidences of old breaks, particularly in the furculum and keel, were higher with aviary and free-range systems so that the total fracture incidences did not differ greatly between different housing systems, as shown in Table 23.2 (Gregory *et al.*, 1990). Increasing the height of cages has been found to increase humerus strength, perhaps as a consequence of increased wing stretching or flapping, and this has been associated with decreased humerus fracture incidence (Moinard *et al.*, 1998). This study also found that fitting a perch in the cage increased humerus strength. However, later studies have shown particular problems of keel bone fractures and deformities associated with perches. Thus Freire *et al.* (2003) have reported a 73% incidence of keel fractures in a sample of hens kept in a perchery system. Moinard *et al.* (this volume, Part V) found a similarly high incidence (74%) of keel fractures in hens kept in floor pens fitted with perches at different heights and concluded that these fractures were associated with the impact of birds landing on perches rather than with individual bone structure.

It may be concluded that allowing birds more exercise in alternative systems will improve bone strength, but this does not necessarily improve bird welfare. Birds in alternative systems have greater opportunities to experience more damaging accidents than caged birds. For instance, they can have impacts during flight or landing, or fall or be pushed off perches. More research is needed to establish designs and stocking densities for alternative husbandry systems that will minimize

Table 23.2. Fracture incidences (%) after depopulation of hens from different husbandry systems.

	Husbandry system		
	Cages	Perchery	Free-range
New breaks	31	10	14
Old breaks	5	25	12
Total	36	35	26

Data from Gregory *et al.* (1990).

welfare problems associated with bone fractures. However, alternative systems are also associated with other welfare problems, such as feather pecking and cannibalism. Abolition of battery cages is thus not a simple panacea for welfare problems and it is apparent that alternative or additional approaches to minimizing bone fractures are needed.

EFFECTS OF NUTRITION

Nutritional deficiencies of calcium, phosphorus or cholecalciferol have been shown to result in bone loss attributable to osteomalacia (Wilson and Duff, 1991), and are likely to lead ultimately to greater severity of osteoporosis. However, there is no evidence that avoidance of osteomalacia can prevent the development of osteoporosis. A recent study (Rennie *et al*., 1997) investigated the effects of a number of dietary factors during the laying period on bone composition. None of the factors had any effect on the proportions of cancellous bone in spinal (FTV) or leg (PTM) bones but treatments involving feeding a particulate source of calcium (oystershell) or supplementation with fluoride increased the proportions of medullary bone. Providing calcium in particulate form has previously been shown to have beneficial effects on shell quality as well as bone mineralization (Guinotte and Nys, 1991). The finding that provision of calcium with improved digestive characteristics can increase the amount of medullary bone without having much impact on the loss of structural bone shows that calcium deficiency is not a primary cause of osteoporosis. Fluoride is known to stimulate bone formation in other species, but the increase in synthesis in hens is evidently confined to medullary bone. Increases in medullary content may none the less have a beneficial effect on bone quality, as discussed earlier. Confirmation of the practical benefits of particulate calcium sources has been provided by Fleming *et al*. (1998b), who found that feeding limestone particles resulted in improved bone strength in older hens. This effect was probably attributable to the observed increase in medullary bone formation because the treatment had little effect on cancellous bone volumes, as shown in Table 23.3. A further study comparing the effects of a combination of particulate limestone and fluoride has concluded that the benefits were no greater than those from particulate limestone alone (Fleming *et al*., 2003).

Nutrition during rearing is also important in maximizing bone content before the onset of sexual maturity. Dietary supplementation during rearing with extra vitamin K_3 (10 mg menadione/kg, in addition to a normal supplement), a factor required for the synthesis of osteocalcin, a protein involved in bone formation, has been found to result in a higher cancellous bone content in leg bone at point of lay (Fleming *et al*., 1998b). Results from a subsequent study confirmed this effect and showed that the improvement was maintained throughout the laying period, though there did not seem to be any additional benefit of extra vitamin K_3 supplementation during lay (Fleming *et al*., 2003). Plasma osteocalcin concentration during rearing did not show any response to the extra vitamin K_3 supplementation, so the mechanism for the effect and the reason for the preferential effect on cancellous bone are thus unexplained. The advantages of better cancellous bone content in leg bones in relation to osteoporotic bone fracture may be limited since cancellous bone is predominantly in the diaphyseal regions, whereas fractures usually occur in the metaphyseal regions where cortical bone quality is a more important factor.

Table 23.3. Effect of providing limestone as powder or particles (3 mm diameter) on bone characteristics in end-of-lay hens.

Trait	Limestone type		
	Powder	Particles	Probability
Proximal tarsometatarsus			
Total bone (%)	23.4	28.6	<0.001
Cancellous bone (%)	6.6	7.3	NS
Medullary bone (%)	16.8	21.4	<0.05
Free thoracic vertebra			
Cancellous bone (%)	10.4	10.2	NS
Tibia			
Radiographic density (mm Al)	1.96	2.26	<0.01
Breaking strength (kg)	19.5	23.6	<0.05
Humerus			
Radiographic density (mm Al)	0.73	0.78	NS
Breaking strength (kg)	11.8	12.1	NS
Keel			
Radiographic density (mm Al)	0.61	0.68	<0.01

Data from Fleming *et al.* (1998b).

These observations are consistent with the hypothesis that osteoporosis in hens arises as a result of cellular processes rather than nutrient supply and that during the laying period there is continued osteoclastic resorption but little formation of structural bone. The balance of cellular activity can be altered by feeding bisphosphonate, a drug used in human medicine to combat postmenopausal osteoporosis. This acts by inhibiting the action of osteoclasts and has been shown to slow the loss of cancellous bone in hens (Thorp *et al.*, 1993). However, the use of bisphosphonate is unlikely to be a practical solution for laying hen osteoporosis.

GENETIC FACTORS

The large individual variation observed in the bone characteristics of hens at the end of lay, phenotypically unrelated to egg production in a flock of highly productive hens (Rennie *et al.*, 1997), suggests that the problem of osteoporosis may be alleviated by genetic selection, perhaps without any serious consequences for egg productivity.

The possibility of a genetic solution to osteoporosis has been studied by Bishop *et al.* (2000). The inheritance of characteristics related to osteoporosis was studied over five generations in a commercial pure line of White Leghorns previously selected for high egg production. Initially, measurements were made on a range of morphometric, radiological and strength characteristics of different bones in hens at the end of the laying period to determine heritabilities. Morphometric traits involving cancellous and medullary bone volumes were found to be poorly heritable (FTV cancellous bone volume, $h^2 = 0.19$; PTM cancellous bone volume,

h^2 = 0.0). This was considered surprising in view of the use of cancellous bone to assess the severity of human postmenopausal osteoporosis (Khosla *et al.*, 1994) and as a criterion in earlier laying hen studies (Whitehead and Wilson 1992; Wilson *et al.*, 1993; Rennie *et al.*, 1997). In contrast, heritabilities of other characteristics were higher (tibia strength, h^2 = 0.45; humerus strength, h^2 = 0.30; keel radiographic density, h^2 = 0.39). There was also a positive correlation between body weight and bone strength.

A restricted selection index designed to improve bone characteristics, yet hold body weight (BW) constant, was derived from genetic parameters obtained from these preliminary analyses, using standard selection index theory. Three biologically meaningful and moderately to highly heritable traits that could be measured in a short period of time on a large number of birds were included in the index, namely keel radiographic density (KRD), humerus strength (HSTR) and tibia strength (TSTR). By including characteristics of wing, leg and axial skeleton, this index gave a wide representation of the overall skeleton. The index was:

$$\text{bone index (BI)} = (0.27 \times \text{KRD}) + (0.37 \times \text{HSTR}) + (0.61 \times \text{TSTR}) - (0.25 \times \text{BW})$$

The coefficient for bodyweight was increased to 0.35 for selection of the G5 generation to counter a slight divergence in this trait that started to appear between the lines. Selection was performed retrospectively each year, with chickens hatched and raised from all available hens in the experiment. On the basis of the data collected on the hens at the end of their laying period, selection decisions were made with entire full-sib families of chickens being kept or rejected. Selection commenced by assigning birds in generation G3 to either the high (G3H) or low (G3L) line on the basis of their dams' (G2) BI.

CONSEQUENCES OF SELECTION

Genetic parameters for the traits in the BI, and the BI itself, showed that all traits were moderately to highly inherited throughout the study, with the heritability (h^2) of the BI being 0.4. The genetic and phenotypic correlations also show that the three bone measurements in the index were moderately to strongly correlated with each other. Finally, the bone measurements were all positively correlated with body weight, indicating that selection for improved bone strength characteristics alone, without the restriction placed on body weight, would have resulted in considerably heavier birds. Different mean values in the bone strength measurements in different years indicated that these traits were strongly affected by environmental factors, raising the possibility of genotype × environment interactions. However, comparison of full-sib flocks reared at different locations gave little evidence for genotype × environment interactions, within the range of environments investigated.

From year 3 onwards, the lines diverged progressively for KRD, HSTR, TSTR and BI in the desired direction. Bone characteristics in G5 are shown in Table 23.4. For the hens, the lines differed by 19% for KRD, 13% for HSTR, and 25% for TSTR. The differences were highly significant (P<0.01) from year 4 onwards, with the exception of HSTR in year 4, where the difference, although in the desired direction, was not significant. Although selection was based on

Table 23.4. Bone characteristics and body weights at the end of the laying period in female and male chickens after three generations of selection for high (H) or low (L) bone index (G5 generation).

	Females			Males		
	Line			Line		
Trait	H	L	Probability	H	L	Probability
Body weight (kg)	1.67	1.63	<0.001	2.29	2.14	<0.01
Kee radiographic density (mm Al equivalent)	0.58	0.48	<0.001	0.77	0.67	<0.01
Tibia strength (kg)	30.7	23.9	<0.001	68.2	61.5	<0.01
Humerus strength (kg)	15.4	13.5	<0.001	50.0	44.0	<0.05
Humerus fractures (%)	2.8	18.4				

measurements made on hens, selection was found to also affect bone strength in males, with high-index males outperforming low-index males for all traits. The differences between the lines in G5 were: TSTR 10% ($P<0.01$), HSTR 13% ($P<0.05$), KRD 15% ($P<0.01$) and bodyweight 7% ($P<0.01$). The incidences of humeral fractures in hens occurring during the production period and depopulation showed a sixfold difference between the lines in G5. In G9, there is now a twofold difference in tibia strength between the lines at 35 weeks.

Some other bone characteristics of the hens in the two lines are given in Table 23.5. Comparisons of tibia cortical thickness at different ages show that the superior thickness in the high BI line at end of lay is attributable to two factors; namely a greater amount of bone formation during growth and, more importantly, less bone resorption during the laying period. The high-BI hens also contain more medullary bone and fewer osteoclasts, both in relation to the amount of medullary bone and also in absolute numbers in bone sections. These last observations could explain the greater structural bone content in the high-BI hens. The lower number of osteoclasts should result in less total bone resorption over the laying period. A greater content of medullary bone will give a better lining of structural bone, exposing fewer structural surfaces to osteoclastic resorption. The combined result of

Table 23.5. Bone characteristics of hens selected for resistance (H) or susceptibility (L) to osteoporosis.

		Age (weeks)			
Trait	Line	15	25	70	Probability
Tibia cortical width (mm)	H	0.465	0.473	0.422	0.001
	L	0.448	0.447	0.365	
Medullary bone content of proximal tarsometatarsus (%)	H			7.83	0.02
	L	7.83	0.02	6.39	
Osteoclasts/unit of medullary bone	H			979	0.10
	L			1175	

these effects should be a lower rate of structural bone resorption in the high-BI hens.

The responses to selection are encouraging insofar as it appears possible to create sizeable differences in bone strength characteristics of hens in a relatively short period of time, using conventional selection techniques. This response can also be made to be independent of body size, should that be the desire of the breeder, although faster progress could be made if body weight were allowed to increase. Moreover, the absence of significant or meaningful genotype × environment interactions implies that selection progress seen in a breeding flock should also be expressed under commercial egg production conditions.

Although the study was aimed mainly at hens, it is interesting that the bone characteristics included in the BI were also changed in males by selection (Table 23.4), suggesting that selection has altered some factors in bone metabolism common to both sexes. Male chickens do not suffer from osteoporosis but this finding raises the possibility that selection procedures aimed at alleviating osteoporosis in hens could also be carried out in male birds.

Changes in bone strength *per se* are unlikely to be of special interest, however, unless these are accompanied by changes in the incidence of bone fractures. The keel and humerus are two bones observed to be frequently fractured in commercial practice (Gregory and Wilkins, 1989). Although the cage and handling conditions in the present study were not intended to resemble the practices on commercial laying farms, selection has clearly resulted in an altered incidence of fractures in these bones. Few fractures of the tibia, a much stronger bone, were seen in this study. The responses in bone breakage incidence were reflected in the genetic correlations with bone strength. All bone measurements are strongly correlated with the presence/absence of breakages and the number of sites of broken bones, indicating that genetically altering bone strength will indeed alter the incidence of bone fractures.

Can the selection procedure be simplified or improved to avoid the need for retrospective selection performed on excess birds? Bone strengths in different parts of the skeleton appear to be strongly correlated, indicating that selection to improve the strength of one bone within the skeleton should increase the strength of the skeleton as a whole. This has important implications in terms of reducing the number of measurements required to categorize the strength of the skeleton as a whole; relatively few measurements should be required, making selection for bone strength more feasible. Alternatively, selection could be improved by the use of *in vivo* predictors of bone strength at an early stage of the laying period, so that eggs are fertilized, collected and hatched only from selected hens. A predictive *in vivo* method involving digitized fluoroscopy of the humerus under experimental conditions has been described by Fleming *et al*. (2000) in which measurements at 40 weeks give a good prediction of end-of-lay humerus strength. Ultrasound measurements on toe bones in hens during the laying period have also been found to give some indication of overall bone quality (Fleming *et al*., 2004). Tomography can also give an indication of bone quality, but the need for anaesthesia to immobilize live birds for a sufficient length of time to take the measurements may preclude this method from practical use in breeding programmes. Ultimately, the most effective means of selection may involve the use of genetic markers, and research to identify quantitative trait loci (QTL) for osteoporosis resistance and associated candidate genes is currently in progress using intercrosses between the high and low bone index lines.

Table 23.6. Egg production and shell characteristics of hens selected for resistance (H) or susceptibility (L) to osteoporosis.

Trait	Line		Probability
	H	L	
Rate of lay (%)	86.9	87.3	NS
Egg mass (g/hen/day)	51.5	51.8	NS
Feed intake (g/hen/day)	105.2	106.2	NS
2nd grade eggs (%)	2.93	2.30	NS
Candling cracks (%)	3.1	2.6	0.05
Shell wt (mg/cm^2)	79.5	80.5	0.05

RELATIONSHIPS WITH EGG PRODUCTION AND SHELL QUALITY

It is often stated that osteoporosis occurs in hens because they deplete their bones by laying so many eggs. This statement is not totally correct because, of course, hens consume more calcium in their diet than they export in eggs. Studies on relationships between egg production and bone quality in the genetic study of Bishop *et al*. (2000) have not shown any significant difference in mean egg production or egg weight between the high and low BI lines over a laying year, as shown in Table 23.6. Rennie *et al*. (1997) reported correlations in a commercial strain between egg production and trabecular bone content of the proximal tarsometatarsus and free thoracic vertebrae of 0.00 and 0.16, respectively. The initial evidence has thus suggested that egg production has little or no effect on bone quality.

Results of a more detailed investigation of these relationships in a larger flock (n = 500) have been reported briefly (Whitehead, 2004). Hens laying very few eggs had a very high BI (good bone quality) and this resulted in a good correlation between total egg number and BI (r = –0.360; P<0.001). However, when birds laying less than 230 eggs were excluded, the correlation became quite low (r = –0.066; P<0.001). The correlation fell still further when birds laying fewer than 250 eggs were excluded from the analysis (r = –0.055; P<0.001). These results can be explained on the basis that birds laying very few eggs are likely to have long periods when oestrogen levels are low and structural bone formation can take place. Birds laying an intermediate number of eggs are also likely to be out of lay for some periods and are thus able to regenerate structural bone at these times. The very low correlation for birds laying more than 250 eggs is consistent with the theory that birds that are laying regularly will have continuously high oestrogen levels that preclude structural bone formation. However, within the group of birds with egg number in the range of 250–332 eggs, it is still likely that some individuals went hormonally out of lay for a short period during which they were able to regenerate structural bone. This would account for the statistically significant negative, though low, correlation between bone index and egg number seen in this group. These results thus suggest that the major factor in determining the degree of osteoporosis is the length of time that birds are in a continuously reproductive state, not the precise number of eggs laid during that period.

A study by Buss and Guyer (1984) on bone characteristics of thick and thin eggshell lines of chickens concluded that skeletal metabolism was not a limiting

factor determining shell thickness. However, the bone measurements (ash and calcium contents) would not have given any indication of whether there was any relationship between bone structure and shell quality. More insight into relationships between osteoporosis and shell quality has come from the lines generated by the genetic study of Bishop *et al*. (2000). Comparisons between the lines have shown decreased shell thickness and inferior shell quality in the high bone index line (Table 23.6). The relative line difference in shell quality was much less than the difference in degree of osteoporosis; nevertheless this finding establishes the principle that birds more resistant to osteoporosis deposit less calcium in eggshells.

The possible mechanism relating bone and shell quality is of interest. Does less production of shell calcium conserve bone or does a lower rate of bone resorption result in less calcium available for shell formation (i.e. is the mechanism shell-gland- or bone-based)? Consideration of the results from the genetic study, where effects of selection for bone quality were apparent in males as well as in females, might suggest that line differences in bone quality are not dependent upon female reproductive factors, such as shell gland function. The theory proposed earlier, that resistance to osteoporosis is associated with less osteoclastic bone resorption, could imply that birds more resistant to osteoporosis do not mobilize sufficient bone calcium to fully meet their needs for shell formation. Nutritional evidence supports this explanation. It has been shown that provision of a dietary calcium source in particulate rather than powdered form improves both shell and bone quality (Guinotte and Nys, 1991; Fleming *et al*., 1998b). Particulate calcium sources remain in the digestive system longer at night and can provide a greater dietary source of calcium during the period of shell formation, thus making the birds less dependent upon bone mobilization to provide calcium for eggshells.

CONCLUSIONS

Osteoporosis is the major factor predisposing laying hens to the severe welfare problem of bone fractures. It arises from a generalized loss of structural bone throughout the skeleton that starts when the hens start to mature sexually and continues throughout the period of continuing egg production, resulting in progressively weaker bones and increasing fracture risk. When hens go out of lay, structural bone regeneration can recommence and effects of osteoporosis can be reversed. The severity of osteoporosis is increased in hens kept in battery cages, when inactivity contributes to bone loss. The weakened bones in end-of-lay battery hens result in a high proportion of fractures, particularly in wing, keel and leg bones, occurring during depopulation.

The origins of osteoporosis are mainly cellular, but nutrition has a role in helping to counter the condition, firstly by preventing deficiency, which can make the problem worse and, secondly, by promoting good nutrient supply. Providing a particulate source of calcium is particularly helpful.

Keeping birds in alternative husbandry systems that allow them more opportunity for exercise can markedly decrease the severity of osteoporosis. Bones will strengthen in response to the biomechanical forces applied to them. However, hens can still experience high incidences of fractures that occur mainly during their lifetimes within the systems. Although their bones may be stronger, the hens have greater opportunity for more traumatic accidents that can still result in bone

fractures. A particular problem of damage to keel bones is associated with misjudged landings on perches. Thus, replacing battery cages with furnished cages or more extensive systems such as aviaries does not necessarily improve the skeletal welfare of hens.

Bone quality has been found to have a strong genetic component. A divergent selection programme based upon retrospective selection of progeny on the basis of postmortem maternal bone characteristics has resulted in the formation of two lines that show a twofold difference in bone strength after seven generations of selection. The greater bone strength has been shown to result in fewer fractures. The improvement in bone quality in the strong bone line is accounted for by more bone formation during rearing and much less structural bone resorption during the laying period. The latter effect may be related to better protection of structural bone surfaces by more medullary bone, and lower osteoclast number resulting in less bone resorption. Egg production in the two lines is similar, though the strong bone line has slightly poorer eggshell quality. The birds have been selected in cages, but the same improvements in bone strength were seen when the lines were housed in an aviary. The development of more efficient *in vivo* methods for predicting bone quality, perhaps based on genetic markers, will allow selection for better bones to be applied in commercial breeding programmes. Application of this genetic approach should help to solve the problem of bone fractures in laying hens, whatever husbandry system the birds are kept in.

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REFERENCES

Bishop, S.C., Fleming, R.H., McCormack, H., Flock, D.K. and Whitehead, C.C. (2000) The inheritance of bone characteristics affecting osteoporosis in laying hens. *British Poultry Science* 41, 33–40.

Bell, D.J. and Siller, W. (1962) Cage layer fatigue in brown leghorns. *Research in Veterinary Science* 3, 219–230.

Brown, R.H. (1993) Egg producers concerned about loss of spent fowl slaughter market. *Feedstuffs* 65 (52), 1.

Buss, E.G. and Guyer, R.B. (1984) Bone parameters of thick and thin eggshell lines of chickens. *Comparative Biochemistry and Physiology A* 78, 449–452.

Couch, J.R. (1955) Cage layer fatigue. *Feed Age* 5, 55–57.

Fleming, R.H., Whitehead, C.C., Alvey, D., Gregory, N.G. and Wilkins, L.J. (1994) Bone structure and breaking strength in laying hens housed in different husbandry systems. *British Poultry Science* 35, 651–662.

Fleming, R.H., McCormack, H.A., McTeir, L. and Whitehead, C.C. (1998a) Medullary bone and humeral breaking strength in laying hens. *Research in Veterinary Science* 64, 63–67.

Fleming, R.H., McCormack, H.A. and Whitehead, C.C. (1998b) Bone structure and strength at different ages in laying hens and effects of dietary particulate limestone, vitamin K and ascorbic acid. *British Poultry Science* 39, 434–440.

Fleming, R.H., McCormack, H.A. and Whitehead, C.C. (2000) Prediction of breaking strength in osteoporotic avian bone using digitised fluoroscopy, a low cost radiographic technique. *Calcified Tissue International* 67, 309–313.

Fleming, R.H., McCormack, H.A., McTeir, L. and Whitehead, C.C. (2003) Effects of dietary particulate limestone, vitamin K_3 and fluoride and photostimulation on skeletal morphology and osteoporosis in laying hens. *British Poultry Science* 44, 683–689.

Fleming, R.H., Korver, D., McCormack, H.A. and Whitehead, C.C. (2004) Assessing bone mineral density *in vivo*: digitized fluoroscopy and ultrasound. *Poultry Science* 83, 207–214.

Freire, R., Wilkins, L.J., Short, F. and Nicol, C.J. (2003) Behaviour and welfare of individual hens in a non-cage system. *British Poultry Science* 44, 22–29.

Gregory, N.G. and Wilkins, L.J. (1989) Broken bones in domestic fowl: handling and processing damage in end-of-lay battery hens. *British Poultry Science* 30, 555–562.

Gregory, N.G., Wilkins, L.J., Eleperuma, S.D., Ballantyne, A.J. and Overfield, N.D. (1990) Broken bones in domestic fowls: effect of husbandry system and stunning method in end-of-lay hens. *British Poultry Science* 31, 59–69.

Gregory, N.G., Wilkins, L.J., Knowles, T.G., Sørensen, P. and van Niekerk, T. (1994) Incidence of bone fracture in European layers. In: *Proceedings of the 9th European Poultry Conference, Vol. II*. Glasgow, UK, pp. 126–128.

Guinotte, F. and Nys, Y. (1991) Effects of particle size and origin of calcium sources on eggshell quality and bone mineralization in egg laying hens. *Poultry Science* 70, 583–592.

Hudson, H.A., Britton, W.M., Rowland, G.N. and Buhr, R.J. (1993) Histomorphometric bone properties of sexually immature and mature White Leghorn hens with evaluation of fluorochrome injection on egg production traits. *Poultry Science* 72, 1537–1547.

Hughes, B.O., Wilson, S., Appleby, M.C. and Smith, S.F. (1993) Comparison of bone volume and strength as measures of skeletal integrity in caged laying hens with access to perches. *Research in Veterinary Science* 54, 202–206.

Khosla, S., Lufkin, E.G., Hodgson, S.F., Fitzpatrick, L.A. and Melton, L.J. (1994) Epidemiology and clinical features of osteoporosis in young individuals. *Bone* 15, 551–555.

Knott, L., Whitehead, C.C., Fleming, R.H. and Bailey, A.J. (1995) Biochemical changes in the collagenous matrix of osteoporotic avian bone. *Biochemical Journal* 310, 1045–1051.

Knowles, T.G. and Broom, D.G. (1990) Limb bone strength and movement in laying hens from different housing systems. *Veterinary Record* 126, 354–356.

Lanyon, L.E. (1992) Functional load-bearing as a controlling influence for fracture resistance in the skeleton. In: Whitehead, C.C. (ed.) *Bone Biology and Skeletal Disorders in Poultry.* Carfax Publishing, Abingdon, UK, pp. 61–66.

Moinard, C., Morisse, J.P. and Faure, J.M. (1998) Effect of cage area, cage height and perches on feather condition, bone breakage and mortality of laying hens. *British Poultry Science* 39, 198–202.

Newman, S. and Leeson, S. (1998) Effect of housing birds in cages or an aviary system on bone characteristics. *Poultry Science* 77, 1492–1496.

Nightingale, T.E., Littlefield, L.H. and Merkley, L.W. (1972) Osteoporosis induced by unilateral wing immobilisation. *Poultry Science* 51, 1844–1845.

Norgaard-Nielsen, G. (1990) Bone strength of laying hens kept in an alternative system, compared with hens in cages and on deep-litter. *British Poultry Science* 31, 81–89.

Randall, C.J. and Duff, S.R.I. (1988) Avulsion of the patellar ligament in osteopenic laying fowl. *Veterinary Record* 128, 397–399.

Rennie, J.S., Fleming, R.H., McCormack, H.A., McCorquodale, C.C. and Whitehead, C.C. (1997) Studies on effects of nutritional factors on bone structure and osteoporosis in laying hens. *British Poultry Science* 38, 417–424.

Sparke, A.J., Sims, T.J., Avery, N.C., Bailey, A.J., Fleming, R.H. and Whitehead, C.C. (2002) Differences in composition of avian bone collagen following genetic selection for resistance to osteoporosis. *British Poultry Science* 43, 127–134.

Thorp, B.H., Wilson, S., Rennie, J.S. and Solomon, S.E. (1993) The effect of a bisphosphonate on bone volume and eggshell structure in the hen. *Avian Pathology* 22, 671–682.

Urist, M.R. and Deutsch, N.M. (1960) Osteoporosis in the laying hen. *Endocrinology* 66, 377–391.

van Niekerk, T.G.C.M. and Reuvekamp, B.F.J. (1994) Husbandry factors and bone strength in laying hens. In: *Proceedings of the 9th European Poultry Conference,* Vol. II. Glasgow, UK, pp. 133–136.

Whitehead, C.C. (2004) Overview of bone biology in the egg-laying hen. *Poultry Science* 83, 193–199.

Whitehead, C.C. and Wilson, S. (1992) Characteristics of osteopenia in hens. In: Whitehead, C.C. (ed.) *Bone Biology and Skeletal Disorders in Poultry.* Carfax Publishing, Abingdon, UK, pp. 265–280.

Wilson, S. and Duff, S.R.I. (1991) Effects of vitamin or mineral deficiency on the morphology of medullary bone in laying hens. *Research in Veterinary Science* 50, 216–221.

Wilson, S., Duff, S.R.I. and Whitehead, C.C. (1992) Effects of age, sex and housing on the trabecular bone of laying strain domestic fowl. *Research in Veterinary Science* 53, 52–58.

Wilson, S., Hughes, B., Appleby, M.C. and Smith, S.F. (1993) Effects of perches on trabecular bone volume in laying hens. *Research in Veterinary Science* 54, 207–211.

CHAPTER 24
Disease control

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ABSTRACT

The aim of this chapter is to highlight some of the changes that have taken place in disease control methods in the wake of the development of 'alternative' poultry management systems.

When the cage system for intensive egg production was first introduced in the 1950s, most bacterial and parasitic diseases were relatively easily controlled. The subsequent intensification in production then led to an increase in viral diseases, which were successfully controlled with live vaccines. The breeding sector was able to monitor and select in order to eradicate diseases caused by such organisms as *Salmonella pullorum*, *Mycoplasma gallisepticum* and *M. sinoviae*. This enabled producers to purchase disease-free stock and the cage system enabled them to exercise adequate biosecurity to remain free from infection. Red mite was another problem, but the design of modern cage units has enabled producers to control levels of infestation.

The newer 'alternative' systems also rely heavily on the production of high-health-status day-old chicks, and the use of viral vaccination remains widespread. However, the greater exposure to faecal contamination, vermin and wild birds inherent in these 'alternative' systems makes disease control much more difficult than before. The stresses associated with feather loss, cannibalism and predation add to the producers' difficulties in keeping their flocks healthy. The main diseases that need to be controlled are *E. coli* and *Pasteurella* infections, with erysipelas becoming more common. *Salmonella enteriditis* could also become a threat. There are also many health problems caused by parasites such as coccidiosis, blackhead, worms and red mite.

The stresses associated with large colony sizes also play an important part in overall disease control strategies.

INTRODUCTION

The health and welfare of laying hens are inseparable entities. The essence of good stockmanship is to recognize the particular needs of the domesticated species involved. Increasing consumer demands for both broiler chickens and eggs, which started about 60 years ago and have accelerated ever since, especially with the advent of supermarket retailing, have led to greater intensification of production in order to satisfy these demands. With intensification came new diseases.

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VACCINATION

The two most significant viral diseases to emerge with the advent of intensive production were infectious bronchitis and Marek's disease. Both have been controlled effectively with live attenuated virus vaccines, following awareness of the epidemiology and virus identification. This process has continued as new viruses appear and are identified. Today all pullets reared for commercial egg production are vaccinated from 1 day old until point-of-lay (16 weeks) against at least six or eight different viral diseases. Although two of these, Marek's disease and Gumboro disease, are potentially serious and can cause death, they are very nearly 100% controlled. Another, avian encephalomyelitis, is an egg-transmitted disease causing nervous symptoms and death at about 10 days of age. This, too, can be totally controlled by vaccination of the breeding hens.

The remaining diseases prevalent in chickens are of a respiratory nature but also have a marked effect upon egg numbers and egg quality. Whilst vaccination provides the hen with some degree of immunity, the level of challenge and air quality within the housing are significant factors in their control. Hence, single-age, well-ventilated flocks suffer less clinical disease.

In the 1970s, the publication of research concerning the optimum temperature for maximum egg output and feed conversion provided the drive to maintain chicken-house temperatures at the optimum 21°C. This resulted in an increase in respiratory disease problems but subsequently led to a better understanding of ventilation requirements.

Generally speaking, the success of viral vaccinations has continued and modern, intensive, free-range or barn egg production systems suffer relatively little from these infections.

ISOLATION

In the UK, the laying and meat sectors are essentially separate. This has allowed the development of the modern hybrid layer to run parallel with a high health status, which produces day-old chicks guaranteed to be free of infection with *Mycoplasma* and *Salmonella*. Biosecurity on pullet-rearing sites, many of which still retain the advantage of single-age status, ensures that point-of-lay pullets are still free of such diseases, along with their virus immunity.

Pullets entering the cage production system (most, but not all, having been reared in cages) will by-and-large stay free of disease throughout their laying life, which ends when egg output and quality can no longer be maintained at an economic level. Mortality from incidental causes runs at about 4%.

ALTERNATIVE SYSTEMS

The demand for alternative non-cage egg production systems in the 1980s gave rise to huge 'barn' units of 30,000–40,000 birds with multiple tiers of perches, feeders and drinkers above a slatted floor and droppings pit. This system did not last long, due to poor production, excessive egg losses and an obvious welfare nightmare. Whist most 'barn' units now have a much reduced stocking density and

automated egg collection systems, colony sizes still remain large (20,000+ birds). However, provided that they are stocked with healthy, well-vaccinated pullets, disease control remains good. However, if pullets enter the system with a burden of internal parasites such as *Ascaridia* or *Coccidia*, these will develop further as the birds have access to infested droppings and recycle them naturally. The provision of a 'scratching' area makes this situation worse, especially if it becomes wet and badly soiled with faeces. Occasionally, *E. coli* septicaemia losses will arise as the birds reach the stress period of peak egg production. This will be made worse should any respiratory virus activity be present, as mentioned above.

Red mite can build up rapidly in this system and have been very difficult to control, leading to bird discomfort, feather pecking, production losses, and occasionally death due to anaemia.

The general level of disease, and for that matter performance, has depended upon the stockman's ability to maintain an equilibrium of social behaviour in the flock. Given that the feed supplies adequate levels of protein and sodium, the key is then to avoid feather pecking. This can generally be achieved by reducing the light intensity immediately after signs of feather loss appear. Flocks vary greatly in their feather pecking habits and clearly the conditions of rearing have a bearing on this. An inability to control feather loss leads immediately to an increase in *E. coli* septicaemia, egg peritonitis and loss of eggshell quality. Clearly the flock becomes very stressed in these conditions.

Control of egg size is another important factor in controlling disease. Once average egg size exceeds about 65 g, then losses due to egg peritonitis and septicaemia increase.

'Free-range' egg production for supermarket sale utilizes a similar housing system, with around 4000–6000 birds involved but with access to the outside. Hence, the same difficulties arise as for the barn system, with the added complications of loss of some light control, access to soiled pasture and predation. Disease control is very much more difficult in this situation and depends a great deal more on good day-to-day management, and the ability of the stockman to respond quickly to any problem that arises.

With a static house and the same pasture each time, a new flock of pullets faces an unknown challenge and all too frequently the levels of challenge give rise to disease. Ascarid worms, coccidiosis, and particularly *E. coli* organisms are common causes of disease as a result. *Pasteurella* and *Erysipelas* organisms are also easily introduced if vermin are not kept under control. As yet, *Salmonella* spp. have not yet appeared in these systems, but clearly there is a danger. Attempts to rotate birds in paddocks around the house have helped, but good drainage is also essential.

Fox predation is ongoing, and to some extent accepted, but cannot be allowed to get out of control. Where the whole paddock is fenced effectively and popholes left open all the time, bird welfare is markedly improved, leading to better feather cover and less disease. In certain circumstances, buzzards and even seagulls have caused losses.

CONCLUSION

Health and welfare are clearly linked, but not always in predictable ways. Sixty years ago, the stockman's attempts to improve health led to the development of a production system which incorporated some poor welfare standards, whereas the last 20 years have seen an attempt to improve welfare, sometimes at the expense of health.

Unfortunately, the overriding market-led demands of the retailer and acceptance of schemes such as 'Freedom Food' have not helped, as the essential parameters of health were not taken into consideration. In the quest for improved 'welfare', as seen through the eyes of the consumer and the retailer, the concerns of stockmen and veterinarians were overruled. Intensive egg production outside the cage system will always be more prone to disease, and hence control of disease must be an essential part of the monitoring system if bird welfare is to really benefit. On some farms, disease control has recently become too difficult and production has ceased altogether.

CHAPTER 25
Environmental management for laying hens

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ABSTRACT

Traditionally, environmental management of laying hens has been directed more towards optimal production than towards the hen's welfare. We have acquired an excellent understanding of the production responses of the laying hens to their climatic environment, such as air temperature, humidity and velocity. Air temperature is of particular interest because of its correlation with other aspects of the hen's thermal and atmospheric environment. Both experimentally and in practice, air temperature has a significant effect on feed conversion, egg numbers and size, and the concentration and emission of ammonia and airborne dust. Fortuitously, production and welfare criteria coincide for the thermal environment, and financially driven targets are available. There are also clear targets for the light environment using production norms (see Perry, this volume, Chapter 26), but guidelines for the major aerial pollutants are still under consideration following recent work. Environmental management for the laying hen, therefore, comprises more than the provision of a thermostat in a well-ventilated and insulated building.

For housed hens, the main problem for the environmental engineer is to remove heat and moisture: most hen houses are ventilated mechanically to control air temperature. The required ventilation rates for different ambient conditions can easily be calculated from the gas, moisture and heat balances of the building. The sensible and latent heat production is well known for laying hens kept in battery cages, and recent research has determined the values for hens kept in alternative cage and aviary systems.

The first priority to improve climate control for housed hens is accurate control of ventilation rate throughout the building. Suitable equipment is available, but is not being used currently in most buildings. Another problem is the inhomogeneous distribution of air temperature throughout the building's volume and over time. Spatial gradients of up to 5°C in cage systems can depress production.

The airflow pattern is the physical link between the air entering the building and the micro-environment around the hens. This means that the accurate control of airflow pattern is the second priority. Efficient, simultaneous control of both air temperature and airflow pattern by varying ventilation rate requires a separate sensor and control system for airflow pattern. This technology is under development but is not yet generally available for livestock buildings. Its availability would allow much greater control of the thermal and atmospheric environment inside hen houses.

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At present, climate controllers make use of set points (or targets) for environmental variables, which are assumed to be optimal for the typical animal. These set points have been derived from a combination of small-scale laboratory experiments and less rigorous field trials. This approach does not always result in the expected performance of the hen because it over-simplifies the complex interactions between a hen and its environment. We argue that the last step in the development of an optimal climate control for housed animals in general, and laying hens in particular, is online integration of the response of the animals into the climate control actions, otherwise known as *precision livestock farming*.

INTRODUCTION

The role of the environment in promoting good welfare is recognized by many authorities. Indeed, it is part and parcel of some definitions of animal welfare. For example, Fraser and Broom (1990) propose that 'welfare defines the state of an animal as it attempts to cope with its environment'. Here environment is an all-purpose term that includes physical as well as social and other biological factors. Webster's (1995) definition that 'the welfare of an animal is determined by its capacity to avoid suffering and sustain fitness' implies that an animal's interaction with its environment is crucial to good welfare. More specifically, freedom from discomfort is the Second Freedom laid down by the Farm Animal Welfare Council and this can be achieved 'by providing an appropriate environment, including shelter and a comfortable resting area' (DEFRA, 2002). An appropriate environment is specified in the *Code of Recommendations for the Welfare of Laying Hens* (DEFRA, 2002) in terms of ventilation, temperature, noise and light; in the majority of cases exact values are not prescribed, e.g. 'air circulation, dust levels, temperature, relative air humidity and gas concentrations shall be kept within limits which are not harmful to the animals'. However, clear guidelines exist and the technical means by which they can be met are considered in this chapter.

Guaranteeing a comfortable, healthy environment for the laying hen is therefore an essential component of sound husbandry. This chapter focuses upon the laying hen indoors, where environmental management is interpreted customarily as an optimal thermal environment. There is, however, a growing recognition that the atmospheric and light environments are important too (see Table 25.1; Wathes, 2003; Perry, this volume, Chapter 26). For some pundits, environmental management for laying hens is well understood and practised, but here it is suggested that such a claim is shallowly based and egg producers need to adopt new technologies if the hen's welfare is to be promoted by an appropriate environment within either conventional cages or alternative systems.

DEFINING THE ENVIRONMENT FOR LAYING HENS

The interaction between an animal and its (physical) environment is both complex and dynamic, as recognized by Monteith (1973), who observed that

> the presence of an organism modifies the environment it is exposed to, so that the physical stimulus received *from* the environment is partly determined by the physiological response *to* the environment.

The environment around a laying hen in a hen house or outdoors is customarily defined in terms of climatic variables; the broader definition that embraces social and other biological features is not employed here. Thus the physical environment can be specified by air and radiant temperature, humidity, the concentration of gases, microorganisms and dust, ventilation rate and air velocity, amongst other physical variables.

Each of these variables can vary as a function of time and space. Within the confined space of a hen house, a temporal and spatial average for each variable – such as air temperature – can be calculated on a *building* basis, but its value is limited. In reality, an individual hen does not respond (dynamically) to the average 'air temperature' in this example, but instead to the (changing) air temperature at its location. Consequently, a distinction must be made between the building's air temperature as an average in time and space of all air temperatures in a hen house and the micro-environment of air temperature around a hen. This is defined as the three-dimensional, instantaneous value of air temperature at the hen's location. This distinction is important if one is to understand the success of current environmental control systems for laying hens kept indoors, and what has to be done in future to improve climate control. At present, environmental control is at the level of a building not an individual animal, which in floor-based systems can move throughout the building to occupy a preferred zone.

Laying hens are normally housed in a controlled environment. However, the controlled environment building of modern egg production is a misnomer, since only light (wavelength, photoperiod and illuminance) and air temperature, air speed and ventilation rate can be controlled at a *building* level. A general distinction must also be made between mechanically and naturally ventilated buildings. Environmental control in the former is usually superior to that in the latter, e.g. the pattern of airflow or light. Some designs of mechanical ventilation guarantee a gross flow of air within the building from inlet to outlet but the detailed flow pattern around a hen is still poorly defined.

Air temperature is usually regulated within optimum limits, except during extremely hot or cold weather, but air speed and ventilation rate can be less well controlled because of deficiencies in the original design or poor equipment maintenance. Other variables, such as sound and air quality, are uncontrolled either because sensors and control mechanisms are lacking or control targets are unknown. In practical terms, control of the thermal environment is achieved by the ventilation system, which is now also expected to control the atmospheric environment as well. These dual aims introduce a dilemma for the environmental engineer or farmer since they may be incompatible.

IMPORTANCE OF ENVIRONMENTAL MANAGEMENT FOR THE LAYING HEN

As with other farm animals, the historical objective in housing laying hens was to provide shelter from the extremes of weather. Other advantages became apparent after research in the 1950s and 1960s, particularly the ability to eliminate the seasonality of egg production by controlling the light environment (see Perry, this volume, Chapter 26). The effects of temperature were the next to be studied (see review by Charles and Walker, 2002) and currently there is research on an appropriate atmosphere for laying hens.

The influence of the environment on laying hens has been studied under laboratory conditions and in the field. Three approaches have been adopted (Wathes, 2003). The traditional approach involves response experiments in which groups of hens are kept in controlled environments and their biological responses are measured (e.g. Charles and Walker, 2002). The approach is pragmatic, with direct commercial relevance, but has several limitations. Insight into the underlying physiological, behavioural, immunological and other mechanisms is rarely provided, while subtle outcomes such as welfare that rely on multiple indicators are difficult to interpret. Multifactorial experiments are expensive to conduct and interpretation of third and higher order interactions between environmental variables is complicated. An epidemiological approach using cross-sectional or longitudinal studies overcomes the practical difficulties in providing multifactorial environments but still cannot reveal the underlying causal relationships between environmental stimulus and response. However, the necessary involvement of farmers improves communication of findings but the high cost of the epidemiological approach means that it has rarely been used. The third approach relies on an understanding of environmental perception leading to new ideas about environmental management. This approach is recent and is best exemplified by current work on light (see Prescott *et al.*, this volume, Chapter 15).

Table 25.1 gives examples from the literature that show the importance of environmental management for the laying hen. Many environmental variables directly influence process variables that relate to the hen's welfare, e.g. feed consumption, feed conversion, number of eggs, egg weight, eggshell quality, eggshell thickness, thermal stress, mortality, and eating behaviour. This information can, in turn, be translated into recommended values or targets for some environmental variables, as shown in Table 25.2.

ENVIRONMENTAL MANAGEMENT: FIVE LOGICAL STEPS

Successful environmental management for the laying hen therefore requires: (i) clear targets for the environmental variables of interest; and (ii) a control system that comprises environmental sensors, a controller and an effector mechanism or actuator: for example, control of the thermal environment is effected by the ventilation system linked to a thermostat. These requirements are best illustrated for the thermal environment in a hen house, although the same approach could be used for other environmental variables, such as the concentration of aerial pollutants.

Step 1: Building Temperature Control

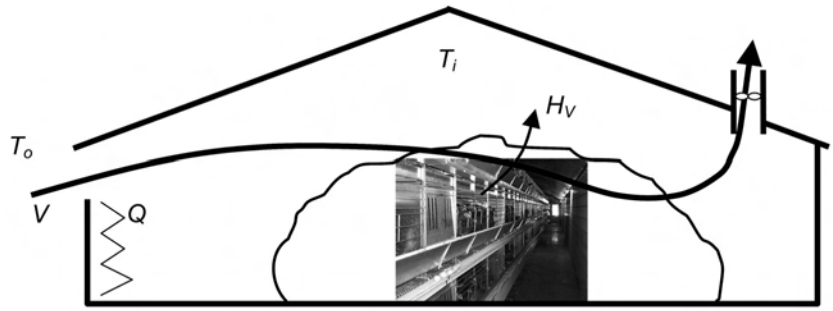
For the laying hen, temperature – at the gross level of the building – is an important environmental variable to control (Table 25.1). Indeed some authors argue strongly that 'if the thermal environment is correct for a flock in a well-designed house, other aspects of the physical environment are acceptable as well' (Webster and Czarick, 2000). This view is debatable because of the potential conflicts between the thermal and atmospheric environments. Temperature control is achieved by varying the ventilation rate of a (well-insulated) building.

Table 25.1. Importance of environmental management for the laying hen.

Focus of environmental management	Example(s)	Reference
Shelter	Protection of birds from unfavourable weather conditions and predators	Austic and Nesheim, 1990
Production	Air temperature and feed consumption	Mahmoud *et al.*, 1996; Roland *et al.*, 1997
	Air temperature and feed conversion	Chepete and Xin, 2000; Yanagi *et al.*, 2002
	Air temperature and egg production	Timmons and Gates, 1988; Lokhorst,1996; Roland *et al.*, 1996; Samara *et al.*, 1996; Okumura *et al.*, 1988
	Light colour and number of eggs	Rozenboim *et al.*, 1998
	Light schedule and egg weight	Tucker and Charles, 1993
Product quality	Air temperature and eggshell quality	Mahmoud *et al.*, 1996; Samara *et al.*, 1996
	Light schedule and shell thickness	Tucker and Charles, 1993
Environmental impact	Temperature and NH_3 emission	Groot Koerkamp, 1994
	Airflow pattern and odour emission	Müller, 2002
	Temperature and dust emission	Guarino *et al.*, 1999
Health and welfare	High temperatures and thermal stress	Barnett and Newman, 1997
	Air velocity and sprinkling and heat stress	Bottcher *et al.*, 1991; Ikeguchi and Xin, 2001; Yahav *et al.*, 2001
	Air mixing and contaminant concentration	D'Alfonso *et al.*, 1996
	Dust, NH_3 and bacteria and lung lesions	Appleby and Hughes, 1991
	Dust and mortality	Guarino *et al.*, 1999
	Light schedules and mortality	Lewis *et al.*, 1992
	Illuminance and eating behaviour	Prescott and Wathes, 2002

Table 25.2. Recommended values for some environmental variables.

Environmental variable	Value	Reference
Temperature	21°C	Appleby and Hughes, 1991
	21–25°C	Chepete and Xin, 2000
		Yanagi *et al.*, 2002
Humidity	50–90%	Seedorf *et al.*, 1998a
Ventilation rate	min. 175 m^3/h, 500 kg	Seedorf *et al.*, 1998b
	max. 2000 m^3/h, 500 kg	
Light intensity	Cages: ≥5 lx	Prescott and Wathes, 2002
	Other systems: ≥10 lx	
Ammonia concentration	10 ppm or lower	Wathes *et al.*, 2002



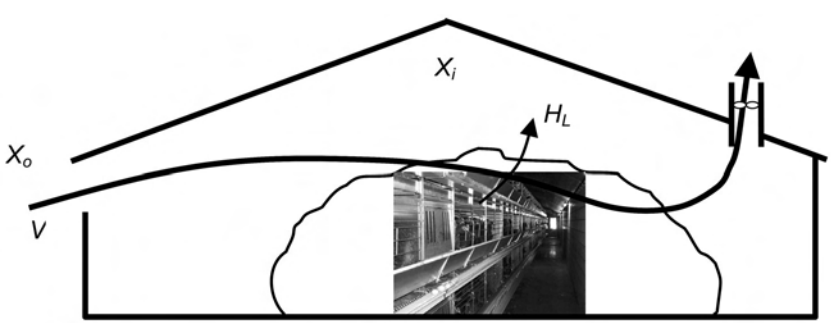
$$H_V + Q = V \cdot \gamma \cdot c_{DA} \cdot (T_i - T_o) + \Sigma\, k \cdot s \cdot (T_i - T_o)$$

Fig. 25.1. Calculation of the sensible heat balance; H_V = sensible heat production (J/s), Q = heat supply ($Q > 0$, $Q < 0$)(J/s), V = ventilation rate (m^3/s), γ = air density (kg DA/m^3), c_{DA} = heat capacity of dry air (J/kg DA.°C), k = heat transfer coefficient (J/s.m^2.°C), S = surface area of heat exchange (m^2), T_i = (desired) inside air temperature (°C), T_o = outside air temperature (°C).

Step 2: Ventilation Rate Control

Consideration of the energy balance of a hen house shows that control of ventilation rate is of great importance. Given the simplifying assumption of perfectly mixed air in the house and consequently a homogeneous temperature under steady state conditions, then the balance of both sensible heat and moisture can be determined and used to calculate the ventilation rate needed to control air temperature and/or humidity in the poultry house (Figs 25.1 and 25.2).

One main task in environmental control, therefore, is to remove the heat and moisture generated by the birds from the building. Ventilation of a building at a rate that is sufficient to maintain thermal comfort will nearly always ensure that the concentrations of oxygen and carbon dioxide remain within acceptable limits, though



$$\frac{H_L}{\varepsilon} + W = V \cdot \gamma \cdot (X_i - X_o)$$

Fig. 25.2. Calculation of the moisture balance; H_L = latent heat production (J/s), V = ventilation rate (m^3/s), W = moisture supply/removal (kg H_2O/s), γ = air density (kg DA/m^3), ε = latent heat of vaporization of water (J/kg H_2O), X_i = absolute inside humidity (kg H_2O/kg DA), X_o = absolute outside humidity (kg H_2O/kg DA).

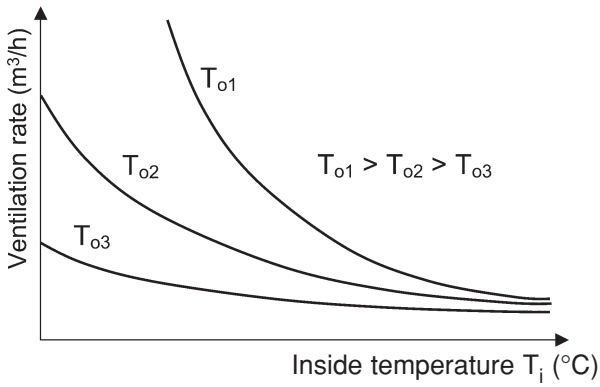


Fig. 25.3. The relationship between the target value of inside temperature (T_i), the outside temperature (T_o) and the ventilation rate (V), assuming Q = 0 in the sensible heat balance.

this is not necessarily true for other aerial pollutants such as ammonia or dust. The relationship between the target value of inside temperature, outside temperature and ventilation rate of the building shows the importance of ventilation rate in determining inside temperature (Fig. 25.3). This is known as the process curve. Due to the characteristics of axial fans, which are commonly used, and their sensitivity to pressure variations (e.g. wind action, air inlet control etc.), online measurement of ventilation rate is needed if the inside temperature is to be controlled successfully (Berckmans and Goedseels, 1986). In practice, many cases of high temperature in hen houses are due to poor use of climate controllers and the absence of effective control of ventilation rate.

Step 3: Control of the Airflow Pattern

Control of building temperature by using an appropriate ventilation rate does not guarantee control of either airflow pattern or temperature distribution within a hen house. D'Alfonso *et al*. (1996) measured temperature in two houses (204 × 21 m) for laying hens at 48 different positions and found spatial temperature differences of up to 8°C. Similar gradients in practice were measured by Kuney (1998). The physical link between fresh air entering the building and the micro-environment around the hens is determined by the three-dimensional airflow pattern. Control of airflow pattern is therefore also needed to guarantee good management of temperature distribution within the building's volume. Efficient and simultaneous control of both air temperature by regulating ventilation rate and airflow pattern at each level of ventilation rate and outside temperature requires the use of a separate sensor for airflow pattern. Such control can be realized by incorporating an airflow pattern sensor into the ventilation system (Schuyesmans *et al*., 2002).

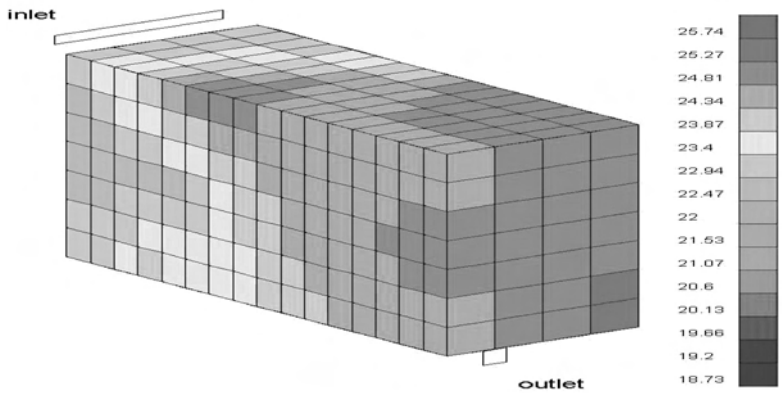


Fig. 25.4. Measured three-dimensional temperature gradients in an empty ventilated test room ($3 \times 2 \times 1.5$ m).

Step 4: Control of the Micro-environment

The three-dimensional airflow pattern always plays an important role in environment control and leads to spatial inhomogeneity in air temperature, humidity and other micro-environmental variables. This is illustrated by the gradients in temperature in a ventilated test room ($3 \times 2 \times 1.5$ m), which can be high (see Fig. 25.4).

Gradients in the physical environment may affect animal welfare and production performance. For example, spatial and temporal variations in egg weight have been shown to be due to gradients in the physical environment (Table 25.3; Roland *et al.*, 1997). Ketelaars' data demonstrate that the hen's response to temperature depends on whether she is housed in cages or on the floor.

Step 5: Control of the Environmental Responses of the Laying Hen

Of course, the laying hen herself is the most important component in an environmental control system, i.e. the way she performs in terms of welfare, health, production etc. At present, climate controllers make use of set points that are assumed to be optimal for the 'typical bird'. This approach does not always result in the expected performance or welfare since it oversimplifies the complex interactions between a hen and her micro-environment. If the final objective remains to promote – or even control – the hen's welfare then it is logical to measure online the hen's responses to the process inputs and to integrate these in control of the environment (Aerts *et al.*, 2000, 2003a,b). This control technology is termed an integrated management system or precision livestock farming for laying hens (Fig. 25.5). The principles of this technology are described elsewhere (Aerts, 1991, 2001; Berckmans and Aerts, 1996; Wathes *et al.*, 2001).

As in every efficient control system, the hen's bio-responses to her micro-environment must be measured, predicted and controlled. In this example, the responses are described and predicted by an online mathematical model. The

Table 25.3. Effect of air temperature on eggs per hen-day, egg weight, feed consumed per hen per day and feed conversion ratio for hens housed in cages and a floor system (after Ketelaars *et al.*, 1985)

Age (days)	Temp (°C)	Eggs per hen-day		Egg weight (g)		Feed consumed per hen per day (g)		Feed conversion	
		Cage	Floor	Cage	Floor	Cage	Floor	Cage	Floor
302	20	0.91 (0.01)	0.83 (0.01)	64.8 (0.40)	62.9 (0.80)	130 (1.25)	120 (0.15)	2.25	2.29
305	23	0.89 (0.06)	0.87 (0.00)	64.8 (0.47)	62.7 (0.15)	129 (2.01)	130 (3.65)	2.25	2.38
308	26	0.88 (0.02)	0.86 (0.02)	64.8 (0.28)	63.1 (0.45)	124 (1.90)	126 (1.30)	2.19	2.31
311	29	0.83 (0.04)	0.87 (0.02)	63.8 (0.44)	62.6 (0.40)	111 (1.35)	121 (1.75)	2.10	2.22
314	32	0.72 (0.07)	0.82 (0.00)	63.1 (0.09)	62.5 (0.20)	89 (3.29)	109 (1.45)	1.98	2.16
317	32	0.71 (0.01)	0.80 (0.01)	61.0 (0.63)	61.4 (0.20)	76 (2.54)	104 (1.70)	1.75	2.11
320	29	0.68 (0.03)	0.83 (0.02)	60.5 (0.11)	62.7 (0.45)	84 (1.65)	113 (1.95)	2.06	2.16
323	26	0.68 (0.04)	0.81 (0.01)	61.1 (0.64)	62.5 (0.20)	99 (2.24)	121 (4.75)	2.41	2.38
326	23	0.68 (0.03)	0.83 (0.02)	62.3 (0.44)	62.7 (0.10)	113 (2.75)	122 (1.80)	2.65	2.36
329	20	0.72 (0.08)	0.78 (0.01)	62.2 (0.62)	63.0 (0.05)	118 (2.12)	127 (4.80)	2.65	2.56

Standard deviations in parentheses.

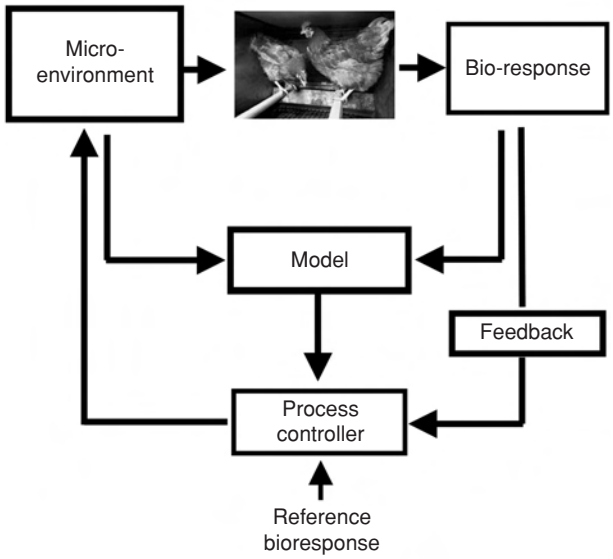


Fig. 25.5. Schematic overview of an integrated management system or precision livestock farming system applied to the environmental management for laying hens.

responses could be physiological, behavioural or production, in fact any measure that can be related either directly or indirectly to welfare, e.g. heart rate, cortisol level, specific behaviours or metabolic rate. Given: (i) a target or reference value for the bio-responses, and (ii) a means to sense these, then the predicted responses are used in a process controller to adjust the micro-environment to produce the desired bio-response. At present, this concept has only been demonstrated in the laboratory, e.g. control of heat production in response to temperature or light intensity (Aerts *et al.*, 2002, 2003b), and its potential to improve animal welfare has yet to be proven. The initial step of continuous monitoring of a hen's state certainly offers an advantage over current practice.

Several sensing techniques are under development to measure the biological responses of laying hens in real time, e.g. individual bird weight (Lokhorst, 1996) and behavioural variables such as scratching, eating, drinking, resting, spreading the wings etc. (Leroy *et al.*, 2003). In future, online monitoring of the responses of laying hens will allow prediction of their behaviour and an improved control of welfare by manipulation of the hen's micro-environment.

ENVIRONMENTAL MANAGEMENT AND HEN WELFARE IN DIFFERENT SYSTEMS OF PRODUCTION

Traditional cage systems for laying hens will be effectively banned in the UK by 2012 if European Directive 1999/74/EC is implemented. Alternative production systems are being introduced in their stead, e.g. enriched cages, single or two-tier aviaries and free-range systems. Whether or not environmental management in these alternative systems will lead to better or worse welfare compared with

conventional cages is a crucial question. However, there are few studies in which this is addressed directly, though inferences can be drawn from some existing work.

Table 25.4 shows the mean concentrations over 24 h of three major aerial pollutants in hen houses fitted with either conventional cages or aviaries/percheries. Overall the burden of aerial pollutants to which the hens were exposed was significantly worse in the aviaries/percheries; this would present a greater hazard to the bird's health (see Wathes, 2003). Whyte (2002) provides supporting evidence that the occupational exposure of stockmen to aerial pollutants was significantly greater in barns than cage systems. There was no difference between the mean air temperature and humidity in the two systems (Seedorf *et al.*, 1998b), although the short period (of 24 h) over which the measurements were made and the small number of sampling locations (six in each building) demonstrate the need for a much more detailed study, along the lines of D'Alfonso *et al.* (1996).

Environmental management of free-range hens when they are in their buildings is likely to be similar to that of hens in aviaries. Once outdoors little needs to be done to modify the thermal environment except for the provision of shade and windbreaks: thermoregulatory demands will be higher and will be readily met. The thermal comfort of the 'well fed, well-feathered hen strutting in a dry, sheltered barnyard at 10°C' is good (Webster, 1995), though she costs the farmer more money by eating more food. Outdoors she will be exposed to few, if any, aerial pollutants.

Environmental management of hens in enriched cages will therefore present

Table 25.4. Mean concentrations of inhalable dust, ammonia and endotoxin in the atmosphere in either hen houses with conventional cages or aviaries/percheries.

	Conventional cages	Perchery or aviary
Inhalable dust concentration[a] (mg/m^3)		
England	1.5	2.2
The Netherlands	0.8	8.8
Denmark	1.6	4.9
Germany	1.0	–
Ammonia concentration[b] (ppm)		
England	11.9	8.3
The Netherlands	5.9	29.6
Denmark	6.1	25.2
Germany	1.6	–
Endotoxin concentration[c] (ng/m^3)		
England	549	2816
The Netherlands	21	431
Denmark	116	265
Germany	31	–

[a]Takai *et al.*, 1998; [b]Groot Koerkamp *et al.*, 1998; [c]Seedorf *et al.*, 1998c. Each building was surveyed over 24 h in the winter and the summer using standard methods. The number of buildings with cages or aviaries/percheries were 4 and 4 in both England and The Netherlands, and 3 and 1 in Denmark, respectively; and 4 buildings with cages only in Germany.

additional technical requirements to those of conventional cages. Poorer air quality in aviaries and barns will be detrimental to the hen's welfare and additional measures will be needed to reduce the burden of aerial pollutants. Further, the design of ventilation systems in aviaries and barns has not received the same attention as that in conventional cage systems and the geometry of the equipment and furniture imposes new requirements if the thermal environment is to be managed effectively.

CONCLUSIONS

Welfare, health, production, egg quality and environmental impact are strongly influenced by environmental management in the laying house. The principles of environmental management are well understood but are not incorporated in current systems on the farm. Precision livestock farming offers one means by which welfare may be improved, provided that appropriate measures of welfare can be identified and sensing systems devised. Environmental management of hens in alternative systems presents additional requirements beyond those in conventional cage systems and welfare may be worse until new systems of environmental management are designed and tested.

REFERENCES

Aerts, J.-M. (1991) Development of an experimental installation for modeling the responses of a living organism. Masters thesis, Katholieke Universiteit Leuven, Leuven, Belgium.

Aerts, J.-M. (2001) Modelling of bioresponses to micro-environmental variables using dynamic data-based models. PhD thesis, Katholieke Universiteit Leuven, Leuven, Belgium.

Aerts, J.-M., Berckmans, D., Saevels, P., Decuypere, E. and Buyse, J. (2000) Modelling the static and dynamic response of total heat production of broiler chickens to step changes in air temperature and light intensity. *British Poultry Science* 41, 651–659.

Aerts, J.-M., Wathes, C.M. and Berckmans, D. (2001) *Applications of process control in poultry production*. British Society of Animal Science Occasional Publication No. 28, 147–154.

Aerts, J.-M., Van Buggenhout, S., Vranken, E., Lippens, M., De Groote, G., Decuypere, E. and Berckmans, D. (2002) Model-based control of the growth trajectory of broiler chickens. In: *AgEng2002*, 30 June – 4 July, Budapest, Hungary, paper no. 02-AP-019.

Aerts, J.-M., Lippens, M., De Groote, G., Buyse, J., Decuypere, E., Vranken, E. and Berckmans, D. (2003a) Recursive prediction of broiler growth response to feed intake by using a time-variant parameter estimation method. *Poultry Science* 82, 40–49.

Aerts, J.-M., Wathes, C.M. and Berckmans, D. (2003b) Dynamic data-based modelling of heat production and growth of broiler chickens: development of an integrated management system. *Biosystems Engineering* 84, 257–266.

Appleby, M.C. and Hughes, B.O. (1991) Welfare of laying hens in cages and alternative systems: environmental, physical and behavioural aspects. *World's Poultry Science Journal* 47, 109–128.

Austic, R.E. and Nesheim, M.B. (1990) *Poultry Production*. Lea and Febiger, Philadelphia.

Barnett, J.L. and Newman, E.A. (1997) Review of welfare research in the laying hen and the research and management implications for the Australian egg industry. *Australian Journal of Agricultural Research* 48, 385–402.

Berckmans, D. and Aerts, J.-M. (1996) Modelling of bioresponses for monitoring and control of enclosed systems. *First Symposium on the Utilisation of the International Space Station,* September 30–October 2, Darmstadt, Germany, pp. 163–166.

Berckmans, D. and Goedseels, V. (1986) Development of new control techniques for the ventilation and heating of livestock buildings. *Journal of Agricultural Engineering Research* 33, 1–12.

Bottcher, R.W., Baughman, G.R., Gates, R.S. and Timmons, M.B. (1991) Characterizing efficiency of misting systems for poultry. *Transactions of the American Society of Agricultural Engineers* 34, 586–590.

Charles, D.R. and Walker, A. (2002) *Poultry Environment Problems: a Guide to Solutions*. Nottingham University Press, Nottingham.

Chepete, H.J. and Xin, H. (2000) Cooling laying hens by intermittent partial surface sprinkling. *Transactions of the American Society of Agricultural Engineers* 43, 956–971.

D'Alfonso, T.H., Manbeck, H.B. and Roush, W.B. (1996) A case study of temperature uniformity in three laying hen production buildings. *Transactions of the American Society of Agricultural Engineers* 39, 669–675.

DEFRA (2002) *Code of Recommendations for the Welfare of Livestock: Laying Hens*. DEFRA Publications, London.

Fraser, A.F. and Broom, D.M. (1990) *Farm Animal Behaviour and Welfare*, 3rd edn. Baillière Tindall, London.

Groot Koerkamp, P.W.G. (1994) Review on emissions of ammonia from housing systems for laying hens in relation to sources, processes, building design and manure handling. *Journal of Agricultural Engineering Research* 59, 73–87.

Groot Koerkamp, P.W.G., Metz, J.H.M., Uenk, G.H., Phillips, V.R., Holden, M.R., Sneath, R.W., Short, J.L., White, R.P., Hartung, J., Seedorf, J., Schröder, M., Linkert, K.H., Pedersen, S., Takai, H., Johnsen, J.O. and Wathes, C.M. (1998) Concentrations and emissions of ammonia in livestock buildings in Northern Europe. *Journal of Agricultural Engineering Research* 70, 79–95.

Guarino, M., Caroli, A. and Navarotto, P. (1999) Dust concentration and mortality distribution in an enclosed laying house. *Transactions of the American Society of Agricultural Engineers* 42, 1127–1133.

Ikeguchi, A. and Xin, H. (2001) Field evaluation of a sprinkling system for cooling commercial laying hens in Iowa. *Applied Engineering in Agriculture* 17, 217–221.

Ketelaars, E.H., Brandsma, H., van der Hel, W., van der Linden, J.M., Verstegen, M.W.A. and Wilbrink, A.J. (1985) Effect of high ambient room temperature on metabolic rate and performance of laying hens in two housing systems. *Netherlands Journal of Agricultural Science* 33, 235–240.

Kuney, D.R. (1998) Temperature mapping of cage layer houses. *1998 California Poultry Symposium*, p. 7.

Leroy, T., Ceunen, J., Vranken, E., Struelens, E., Tuyttens, F., Sonck, B., Janssen, A., De Baere, K., Zoons, J. and Berckmans, D. (2003) Developing a quantitative computer vision method for on-line classification of poultry behavior in furnished cages. *ASAE Paper* No. 034006. ASAE, St Joseph, Michigan, USA.

Lewis, P.D., Perry, G.C., Morris, T.R. and Midgley, M.M. (1992) Intermittent

lighting regimes and mortality-rates in laying hens. *World's Poultry Science Journal* 48, 113–120.

Lokhorst, C. (1996) Automatic weighing of individual laying hens in aviary housing systems. *British Poultry Science* 37, 485–499.

Mahmoud, K.Z., Beck, M.M., Scheideler, S.E., Forman, M.F., Anderson, K.P. and Kachman, S.D. (1996) Acute high environmental temperature and calcium–estrogen relationships in the hen. *Poultry Science* 75, 1555–1562.

Monteith, J.L. (1973) *Principles of Environmental Physics*. Edward Arnold, London.

Müller, H.-J. (2002) The influence of different ventilation and chicken farming systems on the ammonia and odour emission stream. In: *ROOMVENT 2002: 8th International Conference on Air Distribution in Rooms*, Copenhagen, Denmark.

Okumura, J., Mori, N., Muramatsu, T. and Tasaki, I. (1988) Analysis of factors affecting year-round performance of single comb white leghorn laying hens reared under an open-sided housing system. *Poultry Science* 67, 1130–1138.

Prescott, N.B. and Wathes, C.M. (2002) Preference and motivation of laying hens to eat under different illuminances and the effect of illuminance on eating behaviour. *British Poultry Science* 43, 190–195.

Roland, D.A., Bryant, M.M. and Rabon, H.W. (1996) Influence of calcium and environmental temperature on performance of first-cycle (phase 1) commercial leghorns. *Poultry Science* 75, 62–68.

Roland, D.A., Bryant, M., Roland, A. and Self, J. (1997) Performance and profits of commercial leghorns as influenced by cage row position. *Journal of Applied Poultry Research* 6, 284–289.

Rozenboim, I., Zilberman, E. and Gvaryahu, G. (1998) New monochromatic light source for laying hens. *Poultry Science* 77, 1695–1698.

Samara, M.H., Robbins, K.R. and Smith, M.O. (1996) Interaction of feeding time and temperature and their relationship to performance of broiler breeder hen. *Poultry Science* 75, 34–41.

Schuyesmans, S., Vranken, E. and Berckmans, D. (2002) On-line model based control of the airflow pattern in ventilated spaces. In: *AgEng 2002*, June 30–July 4, Budapest, Hungary, pp. 192–193.

Seedorf, J., Hartung, J., Schroder, M., Linkert, K.H., Pedersen, S., Takai, H., Johnsen, J.O., Metz, J.H.M., Groot Koerkamp, P.W.G., Uenk, G.H., Phillips, V.R., Holden, M.R., Sneath, R.W., Short, J.L., White, RP. and Wathes, C.M. (1998a) A survey of ventilation rates in livestock buildings in northern Europe. *Journal of Agricultural Engineering Research* 70, 39–47.

Seedorf, J., Hartung, J., Schroder, M., Linkert, K.H., Pedersen, S., Takai, H., Johnsen, J.O., Metz, J.H.M., Groot Koerkamp, P.W.G., Uenk, G.H., Phillips, V.R., Holden, M.R., Sneath, R.W., Short, J.L., White, R.P. and Wathes, C.M. (1998b) Temperature and moisture conditions in livestock buildings in Northern Europe. *Journal of Agricultural Engineering Research* 70, 49–57.

Seedorf, J., Hartung, J., Schröder, M., Linkert, K.H., Phillips, V.R, Holden, M.R., Sneath, R.W., Short, J.L., White, R.P., Pedersen, S., Takai, H., Johnsen, J.O., Metz, J.H.M., Groot Koerkamp, P.W.G., Uenk, G.H. and Wathes, C.M. (1998c) Concentrations and emissions of airborne endotoxins and micro-organisms in livestock buildings in Northern Europe. *Journal of Agricultural Engineering Research* 70, 97–109.

Takai, H., Pedersen, S., Johnsen, J.O., Metz, J.H.M., Groot Koerkamp, P.W.G., Uenk, G.H., Phillips, V.R., Holden, M.R., Sneath, R.W., Short, J.L., White, R.P., Hartung, J., Seedorf, J., Schröder, M., Linkert, K.H. and Wathes, C.M. (1998)

Concentrations and emissions of airborne dust in livestock buildings in Northern Europe. *Journal of Agricultural Engineering Research* 70, 59–77

Timmons, M.B. and Gates, R.S. (1988) Predictive model of laying hen performance to air temperature and evaporative cooling. *Transactions of the American Society of Agricultural Engineers* 31, 1503–1509.

Tucker, S.A. and Charles, D.R. (1993) Light intensity, intermittent lighting and feeding regimen during rearing as affecting egg production and egg quality. *British Poultry Science* 34, 255–266.

Wathes, C.M. (2003) Environmental management of housed livestock. *Journal of the Royal Agricultural Society of England* 164.

Wathes, C.M., Frost, A.R., Gordon, F. and Wood, J. (eds) (2001) *Integrated Management Systems for Livestock*. Occasional Publication No. 28, British Society of Animal Science, Edinburgh.

Wathes, C.M., Jones, J.B., Kristensen, H.H., Jones, E.K.M. and Webster, A.J.F. (2002) Aversion of pigs and domestic fowl to atmospheric ammonia. *Transactions of the American Society of Agricultural Engineers* 45, 605–1610.

Webster, A.J.F. (1995) *Animal Welfare*. Blackwell Science, Oxford.

Webster, B.A. and Czarick, M. (2000) Temperatures and performance in a tunnel-ventilated, high-rise layer house. *Journal of Applied Poultry Research* 9, 118–129.

Whyte, R.T. (2002) Occupational exposure of poultry stockmen in current barn systems for egg production in the United Kingdom. *British Poultry Science* 43, 364–373.

Yahav, S., Straschnow, A., Vax, E., Razpakovski, V. and Shinder, D. (2001) Air velocity alters broiler performance under harsh environmental conditions. *Poultry Science* 80, 724–726.

Yanagi, T., Xin, H. and Gates, R.S. (2002) A research facility for studying poultry responses to heat stress and its relief. *Applied Engineering in Agriculture* 18, 255–260.

CHAPTER 26
Lighting

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ABSTRACT

Until recent times, interest in lighting conditions largely concentrated on considerations of reproductive performance, including the attainment of sexual maturity, and did not take into consideration the characteristics of the light provided. A detailed consideration of the variety of light sources used in commercial egg production indicates variations in the overall colour emitted due to differences in the component wavelengths. However, the emitted wavelength may also change for a given light source if, for example, the intensity is reduced when feather pecking or cannibalism is detected by the management. Brighter light intensities have been shown to increase bird activities and in some cases have led to increases in feather pecking and higher mortality.

Management guidelines for the provision of light use criteria based on human perceptions, but there are fundamental differences between the structures of the avian and human eye which suggest that the hen has different sensitivities. The characteristics of the lighting provided for housed poultry should therefore reflect the bird's ability to perceive visual images, which enables them to pursue their normal behaviour patterns without any undue stress or decrease in welfare levels.

The duration of the light provided for indoor housed hens in a 24-h period (the photoperiod) is another aspect of lighting which has received attention. Hens are stimulated to eat during the photoperiod and lighting programmes have been developed which are intended to reduce voluntary feed intake and maintain egg output. Some of these have been shown to improve hen health and welfare. By contrast, longer photoperiods have been shown to be associated with higher mortality rates.

This chapter reviews recent findings on avian vision and their implications for the provision of light for laying hens.

INTRODUCTION

It has been known for many years that lighting can influence the reproductive capability of hens (Whetham, 1933; Morris and Fox, 1958). In the past, egg production either ceased or was reduced to low levels during the winter months when short daylight hours were evident. It had been noted that wild bird species commenced lay in the spring as the daylight hours increased and, with the develop-

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ment of intensive indoor production systems in the 1950s, it became possible to create spring-like daylengths at any time of the year using artificial light. The lighting programmes used over the next 50 years contained provision for a gradual increase in photoperiod (the period of illumination per 24 hours) once egg laying had commenced. The reason(s) for this are not clear, although the earlier preoccupation with the increase in natural photoperiod during spring may have encouraged poultry managers to mimic those increases in an attempt to maintain or increase egg output once hens were in lay.

There are two important features to be noted. The adoption of lighting programmes for laying hens occurred without any clear understanding of the mechanisms by which birds perceive the incoming light stimulus. Secondly, the physical properties of the light reaching the birds are determined by the emitting sources, and these could determine the birds' response.

PHOTORECEPTORS

Retinal perception is one of the principal pathways for light detection. Light received by the retina travels along the optic nerve to the hypothalamus. However, Siopes and Wilson (1980) found no difference in the age at sexual maturity between blinded and intact birds, suggesting that the birds were able to perceive stimulatory changes in the photoperiod via an alternative route. Work with other avian species (e.g. house sparrows, Homma *et al.*, 1980) suggested that light could pass through the skull, and other workers (Ali and Cheng, 1985) confirmed this using genetically blind (*rc/rc*) and heterozygous sighted Rc^{+}/rc laying hens (*rc* is an autosomal recessive gene which prevents the development of rods and cones in the retina). These observations led to the discovery that there is a pathway through the skull leading directly to the hypothalamus and this is now recognized as the principal route for photosexual responses. Ali and Cheng (1985) showed that the blinded birds attained sexual maturity earlier than non-stimulated controls. The blinded birds had a higher rate of egg production but consumed less food than the controls, suggesting that the retinal route may influence other aspects of behaviour, such as food intake.

The pathways for incoming light have been summarized in Fig. 26.1.

THE HEN'S EYE

Prescott *et al.* (this volume, Chapter 15) compared the structure of the avian and human eye. The chicken eye possesses three types of photoreceptor: rods, cones and double cones, in contrast to the rods and cones of humans (King-Smith, 1971). Chicken cone cells differ in two respects from their human counterparts. They have four photoreactive pigments associated with the cone cells, compared with three in humans (Yoshizawa and Fukada, 1993). These four pigments are maximally sensitive at 415, 455, 508 and 571 nm wavelengths compared with 419, 531 and 558 nm in humans (Dartnall *et al.*, 1983). They also possess coloured oil droplets which filter light before it reaches the photoreactive pigments. Prescott and Wathes (1999) also showed that the spectral sensitivity curve of the chicken is broader than that of the human.

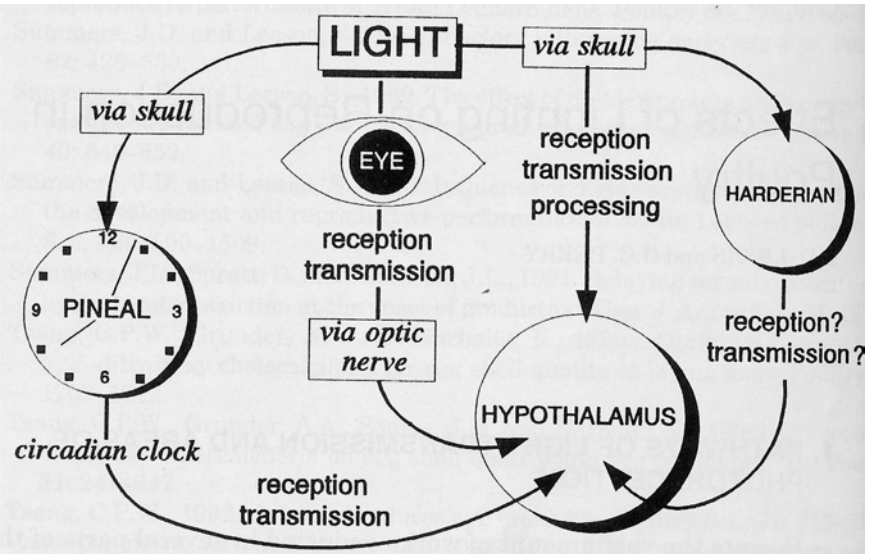

Fig. 26.1. Pathways of light transmission in birds (Lewis, 1987).

Any consideration of the chicken's visual ability, therefore, should not depend on a human analogy but should make allowances for structural differences. It is conceivable that the apparent ability of the chicken to perceive a light stimulus as brighter than humans do is related to the natural environment in which the progenitor of the modern hen evolved. There are subdued light intensities under a tree canopy or around the edges of forests and a more efficient mechanism would enhance visual capability.

LIGHT

There are three important aspects of light which can influence bird behaviour and welfare – *photoperiod*, *intensity* and *wavelength*. Whilst these may act independently, it is possible that they interact.

Photoperiod

Savory and Duncan (1982/83) placed laying hens in Skinner boxes and observed their preference for light or dark. Overall, they preferred light and they were not prepared to work hard for dark. This result emphasizes the importance of the photoperiod and the requirement for lighting programmes which satisfy the needs of the birds for light.

Light has a large influence on the behaviour of hens. Free-ranging hens will move to roosts at dusk and remain inactive during the hours of darkness. They become active again at dawn. The behaviour of birds maintained in windowless houses will also be greatly influenced by the artificially provided photoperiod.

Programmes

Commercial pullets are usually reared on an 8L:16D programme or something very similar. At around 16 or 17 weeks the photoperiod is gradually increased. This was originally thought to stimulate sexual maturity (as with wild birds in spring) but it is now known that modern hybrids possess a sensitivity to light increases from a much earlier age and reach a maximum sensitivity at around 9–10 weeks of age (Lewis *et al*., 1992a). By 16 or 17 weeks of age, hens will have begun to sexually mature and if they remain on 8L:16D will reach maturity by 20–21.5 weeks of age (Lewis *et al*., 1992a). Once egg laying has started, the photoperiod continues to increase up to 14–17L. This is known as a 'step-up' programme.

Once the maximum photoperiod has been attained, commercial practice has developed two broad categories for the provision of illumination in a 24-h cycle containing either one or several photoperiods. An example of a *single photoperiod* cycle is 14L:10D. A programme containing more than one light and dark period in a 24-h cycle is known as an intermittent programme and there are three different types – asymmetrical, short-cycle symmetrical and interrupted.

An example of an *asymmetrical* programme is the 'Cornell' system, e.g. 2L:4D:8L:10D, which contains two unequal periods of light and darkness. Hens interpret the longest dark period as the subjective night and the 2L:4D:8L period becomes their subjective day. The rationale behind this type of programme is that the inserted dark period (4D) encourages the birds to be less active and slightly reduces feed intake, which helps to prevent the development of fatty infiltration of the liver and kidneys. There can be advantages for intensively housed birds because, if the inserted dark period (4D) coincides with the time when ambient temperatures are at a maximum, the reduced activity of the birds will restrict the heat build-up in the house. However, the latest regulations (DEFRA, 2002) state that the dark period must be uninterrupted; therefore asymmetrical programmes should not now be used.

Short-cycle symmetrical programmes are those in which periods of light and darkness are repeated alternately e.g. 4×(3L:3D), known as the 'French' system (Nys and Mongin, 1981). Since all dark periods are of the same length, there is no single long dark period which the birds can regard as 'night', and consequently there is a desynchronization of oviposition times (Nys and Mongin, 1981). Birds require one of the dark periods to be at least 1 h longer than the others in order to identify a night. The rate of lay is less than that in the 'step-up' programmes, but egg size is increased and the overall egg output (g/bird/day) is similar. Shell thickness is increased (Sauveur and Mongin, 1983) and there may be a slight reduction in feed intake (Bougon *et al*., 1982). Short-cycle symmetrical programmes cannot be used under the latest regulations (DEFRA, 2002) for two reasons: they do not follow a 24-h rhythm and the dark period is not uninterrupted.

The *interrupted* system (Snetsinger *et al*., 1979; Midgley *et al*., 1988; Morris *et al*., 1990) is usually introduced after peak egg production has been reached. Each hour (except the last) of the subjective day is divided into periods of 15 min L:45 min D. The final hour is 15 min L:30 min D:15 min L but the programme is presented as 15×(15 min L:45 min D):9D and this is interpreted by the hen as 14.25L:9.75D. Egg output is similar to the 'step-up' programmes but there is a 5% reduction in food intake during the time the interrupted programme is applied.

Morris and Butler (1995) described an improved version (the 'Reading' system) of the interrupted programme comprising 24×(0.25L:0.75D). This programme produced 2% fewer eggs, a 2% increase in egg size, a 3% improvement in shell thickness at the end of the laying year and a 6% reduction in food intake compared with the 'step-up' programme. Mortality was also lower, although not significantly so. Recently, Zoons (this volume, Part V) reported that in houses subjected to the Reading system very few red mites were found at depopulation, in contrast to the houses where an interrupted programme with a 10D component was used. He suggested that the absence of a 'night' in the Reading programme inhibited the mites from feeding on the hens, because they only emerge during long periods of darkness. However, Slaugh *et al*. (1990) compared continuous and intermittent 10L:14D, 12L:12D and 14L:10D regimes and found significantly fewer flies in the intermittent programmes. This result suggests that the reduction in fly populations may be associated with the intermittent part of the photoperiod and not the long 'night'.

The UK Regulations are the vehicle by which the EU Directives are implemented and should therefore be similar to the regulations in other member States. The 1987 UK *Codes of Recommendations for the Welfare of Livestock* (MAFF, 1987) gave imprecise information concerning the photoperiod for domestic fowls. Paragraph 29 stated, 'provision should be made for a period of darkness in each 24-hour cycle, but where birds do not have access to daylight they should be given at least 8 hours lighting per day'. This form of words gave no guidance about the minimum duration of darkness nor the maximum duration of illumination. It also failed to refer to interrupted programmes, although they failed to provide 8L during each 24-h cycle.

Lewis *et al*. (1992b) reviewed 36 sets of mortality data from trials which used intermittent lighting programmes. They concluded that intermittent lighting generally improved bird liveability compared with conventional single photoperiods. Other aspects of hen health and welfare have been shown to benefit from the use of intermittent lighting. Lewis and Perry (1989) showed that hens maintained for a year on 2L:4D:8L:10D had significantly less carcass fat than hens kept on 17L:7D. This was associated with lower body weights, as the regression of fat against body weight was similar in both programmes. The reduced body weight and hence lowered fat deposition may have reduced the incidence of ruptured fatty livers and peritonitis (Lewis and Perry, 1990).

Egg producers in the USA noted that birds subjected to interrupted programmes were quieter, less cannibalistic, and appeared to show reduced signs of stress during hot weather, than conventionally illuminated flocks (Midgley, 1984). Kuit (1985) also observed less vice among intermittently illuminated hens when compared with single-photoperiod illuminated hens and postulated that the general welfare of the intermittently illuminated hens was improved. In 1998, the EU in Council Directive 98/58/EC decreed that laying hens should 'have an appropriate period of rest from artificial lighting' (EU, 1998).

In 2000, DEFRA published the *Welfare of Farmed Animals (England) Regulations*. Again there were no specific durations presented for photo- or scotoperiods.

- Paragraph 14 stated 'animals kept in buildings shall not be kept in permanent darkness'.

- Paragraph 15 stated 'where the natural light available in a building is insufficient to meet the physiological and ethological needs of any animals being kept in it then appropriate artificial lighting shall be provided'.
- Paragraph 16 stated 'animals kept in buildings shall not be kept without an appropriate period of rest from artificial lighting'.

In 2002, DEFRA published the *Welfare of Farmed Animals (England) Amendment Regulations*. In paragraph 3 of Schedule 3D (conditions applicable to all systems) it stated that the lighting regime must follow a 24-hour cycle and include an uninterrupted period of darkness lasting 'about one-third of the day'. It also added that a period of twilight of sufficient duration ought to be provided when the light is dimmed so that the hens may settle down without disturbance or injury.

The EU Directive and the various UK Codes contain little specific guidance concerning the photoperiod or scotoperiod, although the scientific literature has contained much of relevance concerning the photoperiod. It is interesting to note, however, that whereas interrupted programmes could not be used under the previous Codes, the latest Directive and Codes may make some of them, e.g. the interrupted system described earlier, available to the stockman since it provides 'an appropriate period of rest from artificial lighting' (EU, 1998) and the subjective dark period is just in excess of one-third of the day (DEFRA, 2002).

Short-cycle symmetrical programmes could previously be used but not under the DEFRA 2002 Amendment Regulations because they do not have a 24-h cyclicity. This amendment also prevents the use of ahemeral (non-24-h cycles such as 12L:14D) programmes.

Effect of photoperiod on nutrition

Short photoperiods (for example <8 h) may result in hens eating in the dark. The extent to which this occurs depends on the level of egg production and the length of the photoperiod to which the birds are exposed. It should be noted that light *per se* is not essential for egg production (King, 1962) but the absence of illumination makes it impossible for stockmen to carry out normal management practices, including the inspection of the stock.

Long photoperiods (for example >16 h) can lead to excessive intakes of nutrients, particularly towards the end of the laying cycle when egg production is tailing off. Excess nutrients may be deposited as fat in the liver and can lead to an increase in mortality (Lewis *et al.*, 1996). Fifty-week-old laying hens maintained on a 17 h photoperiod showed the birds in a resting position when the lights came on. They did not stand up until 2 h after 'lights-on' and then their relative lethargy (no great urgency to drink or eat) suggested that the birds were 'tired' (unpublished data, University of Bristol).

Lewis *et al.* (1996) analysed data from trials in which two breeds of pullets were reared on an 8 h photoperiod and then transferred to either 8, 10, 13 or 16 h photoperiods. There was a strong correlation between photoperiod and mortality. The mean incidence of mortality was significantly different between the breeds but overall the regression of mortality against photoperiod indicated that mortality increased by approximately 0.8% for each extra 1 h of photoperiod.

The association between photoperiod and feeding behaviour can be seen in Fig. 26.2.

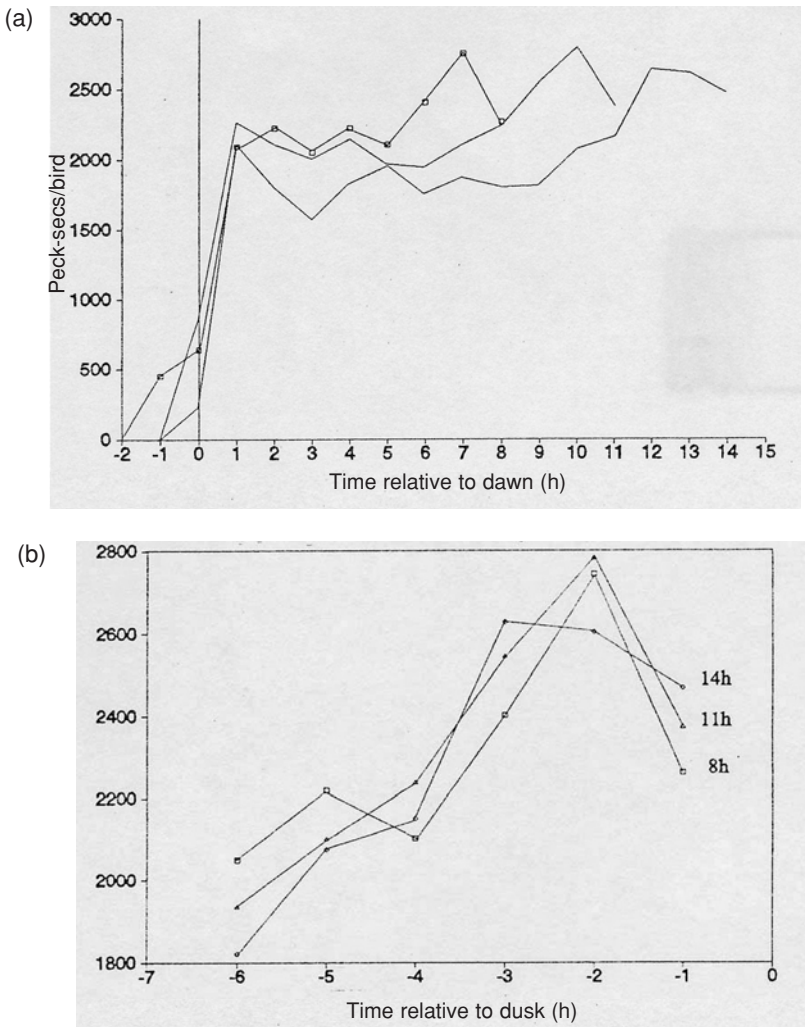

Fig. 26.2. (a) Feeding activity under 8, 11 and 14 h photoperiods; (b) feeding activity in last 6 h of 8, 11 and 14 h photoperiods (Perry and Lewis, 1992).

The rate of feeding appears to maximize at around 2600 peck-secs per bird, therefore birds on short photoperiods cannot compensate by eating at a faster rate. The drive for nutrients is presumably why they commence eating in the dark 2 h before lights-on. It is the circadian rhythm of melatonin secretion which enables the hens to anticipate lights-on and also lights-off since they begin to increase their rate of eating 3 h before lights-off in order to fill their crops.

Birds maintained on the Cornell system show a gradual reduction in feeding activity during the 4-h 'siesta' but exhibit the highest rate during the last 2 h of illumination.

Dawn and dusk

Suggestions that lighting programmes for hens maintained in windowless houses should incorporate a period of dawn, when light intensity gradually increases from darkness, and a period of dusk when intensity fades to darkness, are presumably derived from observations of hens in the wild or exposed to natural illumination. It is indisputable that hens respond to approaching darkness, since they move on to perches to roost up to 2 h before full darkness. As darkness gives way to daylight they come off the perches and begin to seek food. Tanaka and Hurnik (1991) compared the behaviour of indoor-housed birds maintained on a 14L:10D lighting regimen. They noted that birds anticipated both a gradual dawn and abrupt illumination by standing before any change in light intensity. At the beginning of the scotoperiod, almost all the birds were standing during the first minute of darkness when the lights were abruptly turned off but half of them were already sitting at the time full darkness occurred following a period of decreasing intensity. They concluded that gradual changes in illumination could be more comfortable for the birds.

It would appear that hens are able to anticipate the times of changes in illuminance and alter their behaviour accordingly. When 6-week-old caged pullets had their time of sudden 'lights-on' advanced by 2 h, they began to anticipate the earlier time of 'lights-on' within 5 days (unpublished data, University of Bristol). This was evident by the noises made as birds stood up and moved over the wire floors, drank from nipples and pecked in the feed troughs. The same adjustment period of 5 days was also reported by Tanaka and Hurnik (1991) when they switched the lighting treatments from abrupt to gradual changes in their groups of experimental hens. This suggests that hens possess an efficient mechanism for measuring 'time' which operates in the absence of periods of dawn and dusk and is relatively efficient. The requirements for dawn and dusk are therefore ambivalent and require further research.

The above comments assume that there is sufficient time for the birds to obtain their nutrients during the photoperiod and/or there is sufficient feeding space for all birds to satisfy their nutritional needs without having to resort to eating in the scotoperiod.

Light Intensity

The intensity perceived by the hen is influenced by the individual cone responses and Prescott *et al*. (2003) estimated that if fluorescent and incandescent sources were illuminated to the same lux level, which would be isoluminant for humans, hens would perceive the incandescent source to be 20% brighter than the fluorescent tube. This might explain why fluorescent tubes may be used at higher intensities, as perceived by the human eye, than incandescent bulbs without any obvious change in bird behaviour. The light meter commonly used is calibrated to the sensitivity of the human eye and therefore it does not give an accurate indication of the intensity perceived by the hens.

The wild progenitor of the domestic fowl lived at the edges of the jungle where shade would be provided by the tree canopy; therefore it might be anticipated that very bright intensities would not be preferred by the birds.

In current production systems hens can be exposed to a wide range of light

intensities from outdoor conditions and direct sunlight (100,000 lx) to indoor dim lighting (1–2 lx). There is a dearth of scientific information to indicate whether any intensities over this wide range are detrimental to their welfare. Prescott and Wathes (2002) offered hens light intensities of <1, 6, 20 or 200 lx provided by incandescent bulbs and showed that they preferred to eat in 200 lx. They consumed least in the dimmest conditions. Their results agreed with those of Savory and Duncan (1982/83), Davis *et al*. (1999) and Berk (1995).

If an intensity is provided which meets the levels cited in the Codes of Practice recommendations, management should ensure that the sources themselves are regularly inspected to ensure that dust build-up does not occur since this can reduce the radiation output.

The effects of light intensity on egg production have been reported by Lewis and Morris (1999). They reviewed evidence from published trials and concluded that there were small but significant effects of intensity on egg size, food intake and mortality and an economic analysis taking these aspects into consideration indicated that the optimal profit occurred at around 5 lx. They acknowledged that maximizing profit should not be the sole objective and concluded that, due to welfare considerations for both stock and workers, a higher intensity of 10 lx should be recommended. Tucker and Charles (1993), whose data supported the 5 lx biological threshold, also suggested that 10–20 lx should be the minimum intensity on grounds of animal welfare, staff working conditions and aesthetics. Boshouwers and Nicaise (1987) studied the activity of hens under incandescent lights and found that activity was positively correlated with intensity. They suggested that light-independent movements such as feeding, drinking and preening, were 'low strength', but light-dependent movements such as fright and alarm responses were mostly more vigorous. Their results agree with Morris (1967) who found that cannibalism increased at higher light intensities. Williams (1984) highlighted the positive relationship between cannibalism, feather pecking and the number of interactions between birds. The latter was possibly influenced by increased numbers of bird movements at greater light intensities. As feather pecking is one form of interaction between birds, lower light intensities should reduce the incidence of feather pecking and a reduction in light intensity is often used to prevent further pecking once it has been observed. However, it is not clear whether it is the lower light intensity *per se* or the effects of change in the intensity, which often reduces the incidence of pecking.

A review of six publications showed an association between mean daily food intake and light intensity. Overall, mean daily food intake decreased linearly by 0.2 g for each 10 lx increase in light intensity up to 100 lx (Lewis and Morris, 1999). The reviewers were unable to offer an explanation for this effect but pointed out that the decrease was not significant. This observation contrasts with the findings of Prescott and Wathes (2002) cited above, but taken together these results might indicate that both dim and bright lights have a direct effect on voluntary food intake. Lewis and Morris (1999) also cited a negative association between mean egg weight and intensity, but this might be explained by the non-significant reduction in food intake at higher intensities.

Lewis and Morris (1999) also analysed mortality rates and found that they increased between 2 and 5 lx but higher intensities had no further adverse effects. This is surprising, since cannibalism was reported as the principal reason for increased mortality among birds in windowed houses where they would have been

exposed to bright intensities (Bressler and Maw, 1966). Tucker and Charles (1993) suggested that the modern prolific hybrid hen may be more tolerant of low light intensities than were earlier stocks but it is also possible that they may have also become more tolerant towards a wider range of light intensities.

The management practice of reducing intensity to prevent or restrict the development of vices such as feather pecking or cannibalism introduces an interacting factor. A reduction in intensity will influence the wavelengths emitted by the light source and it is possible that any bird response may be due to the changes in wavelength perceived by the hen. In reality, any bird response will most likely be due to the combined effects of intensity and wavelength and it should be remembered that intensity interacts with wavelength.

Wavelength

Wortel *et al*. (1987) derived a spectral sensitivity curve from electrophysiological studies, whereas Prescott and Wathes (1999) obtained theirs from behavioural tests. Both curves differ from the human response curve. This is most obvious at the lower end of the spectrum where fowl possess spectral sensitivity in the ultraviolet A (UV_A) range. This could be of importance when comparing the behaviour and welfare of birds subjected to natural or artificial illuminance.

Many avian species are sensitive to ultraviolet radiation and it has been suggested that this attribute might be involved in bird signalling and therefore individual bird recognition, or foraging activity (Bennett and Cuthill, 1994; Bennett *et al*., 1996, 1997).There is a dearth of information relating to the importance or role of UV light in the management of hens but Lewis *et al*. (2000) exposed laying hens maintained under incandescent lighting to supplementary UV radiation. Their results showed that the UV light had no effect on the timing of the ovulatory cycle but did suppress food intake, and they concluded that UV light is perceived through the retinal route and influences behavioural rather than reproductive responses. Elsewhere, Widowski *et al*. (1992) showed that hens preferred fluorescent to incandescent sources. It is possible that this was influenced by the presence of UV light in the fluorescent spectrum but their preference may have been influenced because they perceived the fluorescent to be dimmer than the incandescent light.

CONCLUSIONS

1. Light has a powerful influence on laying hens. It can influence reproductive performance, voluntary feed intake, liveability and welfare.
2. Light perception through the retina influences behaviour, whereas perception through the skull influences reproductive performance.
3. The hen's eye is structurally different from that of the human, hence issues such as brightness and spectral sensitivity should not be extrapolated from human responses.
4. Hens have been shown to prefer light to dark and brighter rather than dimmer intensities.
5. Longer photoperiods are associated with increased mortality (0.8% for each additional hour of photoperiod).

6. Intermittent programmes can improve health and welfare and specifically a reduction in red mites and fly populations.
7. Hen activity is positively associated with light intensity but increased interactions may be prejudicial to good welfare.
8. As light intensity influences hen activity, scientific reports of hen behaviour should always include details of the light source, intensity and wavelength.
9. There is currently insufficient scientific information to indicate any association between wavelength and welfare.
10. The importance of dawn and dusk requires further research.
11. Hens are sensitive to UV light and it may facilitate individual recognition and hence improve welfare, but more research is needed.
12. Little lighting research has been conducted in enriched cages, barns and free-range systems. More research is needed before clear recommendations can be made about the appropriate wavelengths, intensities and photoperiods which promote high welfare standards.

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REFERENCES

Ali, A. and Cheng, K.M. (1985) Early egg production in genetically blind (*rc/rc*) chickens in comparison with sighted (Rc^+/rc) controls. *Poultry Science* 64, 789–794.
Bennett, A.T.D. and Cuthill, I.C. (1994) Ultraviolet vision in birds: what is its function? *Vision Research* 11, 1471–1478.
Bennett, A.T.D., Cuthill, I.C., Partridge, J.C. and Maier, E.J. (1996) Ultraviolet vision and mate choice in zebra finches. *Nature* 380, 433–435.
Bennett, A.T.D., Cuthill, I.C., Partridge, J.C. and Lunau, K. (1997) Ultraviolet plumage colours predict mate preferences in starlings. *Proceedings of the National Academy of Sciences USA* 94, 8618–8621.
Berk, J. (1995) Light-choice by broilers. In: Rutter, S.M., Rushen, J., Randle, H.D. and Eddison, J.C. (eds) *Proceedings of the 29th International Congress of the International Society of Applied Animal Ethology*. Universities Federation for Animal Welfare, Wheathampstead, UK.
Boshouwers, F.M.G. and Nicaise, E. (1987) Physical activity and energy expenditure of laying hens as affected by light intensity. *British Poultry Science* 28, 155–163.
Bougon, M., Protais, J. and L'Hospitalier, R. (1982) Etudes des performances et de la qualite des oeufs chez des pondeuses soumises a un eclairement discontinue par periodes de trios heures (2e essai). *Bulletin d'information de la Station Experimentale d'Aviculture de Ploufragan* 22, 155–161.
Bressler, G.O. and Maw, A.J.G. (1966) High density and environmental control key to efficient egg production. In: *Proceedings of the X111th World's Poultry Congress, Kiev,* pp. 468–473.
Dartnall, H.J.A., Bowmaker, J.K. and Mollon, J.D. (1983) Human visual pigments: microspectrophotometric results from the eyes of seven persons. *Proceedings of the Royal Society, London: Series B* 220, 115–130.
Davis, N.J., Prescott, N.B., Savory, C.J. and Wathes, C.M. (1999) Preferences of

growing fowls for different light intensities in relation to age, strain and behaviour. *Animal Welfare* 8, 193–203.

DEFRA (2000) *The Welfare of Farmed Animals (England) Regulations*. Department of the Environment, Food and Rural Affairs, London.

DEFRA (2002) *The Welfare of Farmed Animals (England) Amendment Regulations.* Department of the Environment, Food and Rural Affairs, London.

EU (1998) *Council Directive 98/58/EC of July 20 Concerning the Protection of Animals Kept for Farming Purposes*. Document 398L0058: the Council of the European Union.

Homma, K., Ohta, M. and Sakakibara, Y. (1980) Surface and deep photoreceptors in photoperiodism in birds. In: Tanabe, Y. (ed.) *Biological Rhythms in Birds: Neural and Endocrine Aspects*. Japan Scientific Society Press, Tokyo/Springer-Verlag, Berlin, pp. 149–156.

King, D.F. (1962) Egg production of chickens raised and kept in darkness. *Poultry Science* 41, 1499–1503.

King-Smith, P.E. (1971) Special senses. In: Bell, D.J. and Freeman, B.M. (eds) *Physiology and Biochemistry of the Domestic Fowl,* Vol. 2. Academic Press, London.

Kuit, A.R. (1985) Intermittent lighting improves performance. *Poultry International* April, 24.

Lewis, P.D. (1987) Responses of laying hens to interrupted lighting regimes. PhD thesis, University of Bristol.

Lewis, P.D. and Morris, T.R. (1999) Light intensity and performance of domestic pullets. *World's Poultry Science Journal* 55, 241–250.

Lewis, P.D. and Perry, G.C. (1989) Effect of asymmetrical lighting on the body weight and carcass composition of laying hens, and their influence on feed utilisation efficiency. *British Poultry Science* 30, 223–228.

Lewis, P.D. and Perry, G.C. (1990) Response of laying hens to asymmetrical interrupted lighting regimens: reproductive performance, body weight and carcass composition. *British Poultry Science* 31, 33–43.

Lewis, P.D., Perry, G.C. and Morris, T.R. (1992a) Effect of timing and size of light increase on sexual maturity in two breeds of domestic hen. In: *Proceedings of the XIXth World's Poultry Congress, Amsterdam,* Vol. 1, pp. 689–692.

Lewis, P.D., Perry, G.C., Morris, T.R. and Midgley, M.M. (1992b) Intermittent lighting regimes and mortality rates in laying hens. *World's Poultry Science Journal* 48, 113–120.

Lewis, P.D., Morris, T.R. and Perry, G.C. (1996) Lighting and mortality rates in domestic fowl. *British Poultry Science* 37, 295–300.

Lewis, P.D., Perry, G.C. and Morris, T.R. (2000) Ultraviolet radiation and laying pullets. *British Poultry Science* 41, 131–135.

MAFF (1987) *Codes of Recommendations for the Welfare of Livestock: Domestic Fowls: Leaflet 703*. Ministry of Agriculture, Fisheries and Food (Publications), Alnwick, Northumberland, UK.

Midgley, M.M. (1984) *Interrupted Lighting Programmes for Commercial Layers: Report on a Visit to USA*, 8–14 August 1984. Project No. 4 in the Agricultural Service Overseas Study Tour Programme 1984/85. Agricultural Development and Advisory Service.

Midgley, M., Morris, T.R. and Butler, E.A. (1988) Experiments with the bio-mittent lighting system for laying hens. *British Poultry Science* 29, 333–342.

Morris, T.R. (1967) Light requirements of the fowl. In: Carter, T.C. (ed.) *Environmental Control in Poultry Production*. Oliver and Boyd, Edinburgh, pp. 15–39.

Morris, T.R. and Butler, E.A. (1995) New intermittent lighting programme (the Reading system) for laying pullets. *British Poultry Science* 36, 531–535.
Morris, T.R. and Fox, S. (1958) Light and sexual maturity in the domestic fowl. *Nature* 181, 1453–1454.
Morris, T.R., Midgley, M.M. and Butler, E.A. (1990) Effect of age at starting Biomittent lighting on performance of laying hens. *British Poultry Science* 31, 447–455.
Nys, Y. and Mongin, P. (1981) The effects of 6 and 8 hour light–dark cycles on egg production and pattern of ovipositions. *British Poultry Science* 22, 391–397.
Perry, G.C. and Lewis, P.D. (1992) Feeding activity of laying hens under 8, 11 and 14 hour photoperiods. In: *Proceedings of the XIXth World's Poultry Congress, Amsterdam, Vol. 3,* pp. 619–622.
Prescott, N.B. and Wathes, C.M. (1999) Spectral sensitivity of the domestic fowl (*Gallus g. domesticus*). *British Poultry Science* 40, 332–339.
Prescott, N.B. and Wathes, C.M. (2002) Preference and motivation of laying hens to eat under different illuminances and the effect of illuminance on eating behaviour. *British Poultry Science* 43, 190–195.
Prescott, N.B., Wathes, C.M. and Jarvis, J.R. (2003) Light, vision and the welfare of poultry. *Animal Welfare* 12, 269–288.
Sauveur, B. and Mongin, P. (1983) Performance of layers reared and/or kept under different 6-hour light–dark cycles. *British Poultry Science* 24, 405–416.
Savory, C.J. and Duncan, I.J.H. (1982/83) Voluntary regulation of lighting by domestic fowl in Skinner boxes. *Applied Animal Ethology* 9, 73–81.
Siopes, T.D. and Wilson, W.O. (1980) Participation of the eyes in the photostimulation of chickens. *Poultry Science* 59, 1122–1125.
Slaugh, B.T., Johnston, N.P. and Ritz, C.W. (1990) Effect of intermittent and continuous photoperiods on fly populations. *Poultry Science* 69, 867–869.
Snetsinger, D.C., Ragland, W.W., Miller, E.R. and Engster, H.M. (1979) Bio-mittent lighting: a field program for intermittent lighting of pullets and hens. *Poultry Science* 58, 1109.
Tanaka, T. and Hurnik, J.F. (1991) Behavioral responses of hens to simulated dawn and dusk periods. *Poultry Science* 70, 483–488.
Tucker, S.A. and Charles, D.R. (1993) Light intensity, intermittent lighting and feeding regimen during rearing as affecting egg production and egg quality. *British Poultry Science* 34, 255–266.
Whetham, E.O. (1933) Factors modifying egg production with special reference to seasonal changes. *Journal of Agricultural Science* 23, 383–418.
Widowski, T.M., Keeling, L.J. and Duncan, I.J.H. (1992) The preferences of hens for compact fluorescent over incandescent lighting. *Canadian Journal of Agricultural Science* 76, 177–181.
Williams, N.S. (1984) Stress and the behaviour of domestic fowl. *World's Poultry Science Journal* 40, 215–221.
Wortel, J.F., Rugenbrink, H. and Nuboer, J.F.W. (1987) The photopic spectral sensitivity of the dorsal and ventral retinae of the chicken. *Journal of Comparative Physiology* 160, 151–154.
Yoshizawa, T. and Fukada, Y. (1993) Preparation and characterization of chicken rod and cone pigments. In: Hargrave, P.A. (ed.) *Methods in Neurosciences,* Vol. 15. Academic Press, New York, pp. 161–179.

CHAPTER 27
Nutrition, feedstuffs and feeding

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ABSTRACT

The layer diet must allow profitable egg production while taking account of welfare, husbandry systems, health, environmental impact and legal requirements. Since it is impossible to do justice to all these topics in a short review, this chapter will concentrate on aspects of nutrition that impinge on welfare. The diet must provide the chemical components of the egg and also the energy required to convert these substances into egg material. When hens are given a single compound diet, quantity of food and time of eating are the only intake responses available. Under such conditions, intake is a compromise among requirements for individual nutrients. Free-choice feeding has been suggested to allow birds to select for individual nutrient requirements to match rate of egg production. The nutrient and energy contents of the diet affect egg size, number and quality. Calcium and phosphorus content affect shell quality but also interact with bone strength. Yolk colour and egg flavour are functions of the diet. Welfare-related aspects include bone strength, heat stress and direct effects on behaviour. Different modes of feed delivery, such as free-choice feeding, whole-grain feeding, and even whether to use mash or pellets, have welfare implications. Nitrogen excretion (potentially polluting) can be minimized by formulating diets with an amino acid composition as close as possible to the bird's requirements (ideal protein). Adding phytases to the diet makes phytate phosphorus available to the bird, allowing a lower total phosphorus content and reducing phosphorus excretion. For legal or consumer-driven reasons, diets may sometimes have to be formulated without certain raw materials, such as animal protein, genetically modified materials (GMO) or synthetically produced amino acids.

INTRODUCTION

In the early years of large-scale poultry farming, nutritionists might have been excused for thinking that their duty was simply to feed the laying hen for maximum production or maximum profit. It was commonly asserted that if the birds were laying at a rate near their genetic potential then their health and welfare must be acceptable. This assumption is now widely recognized as flawed. Consequently, the nutritionist must now design diets and feeding regimens for production, welfare,

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health, minimal environmental impact and alternative husbandry systems. In some cases there may also be the need to meet nutritional requirements without the use of animal-derived, modified or synthetic ingredients. Egg and shell quality have always been important but now there may sometimes be the added challenge of feeding to create 'designer eggs' as 'functional foods' for the human consumer. It will be impossible to do justice to all these sub-themes in a short review. This chapter will only cover aspects of nutrition that impinge on welfare. Many of the general principles of poultry nutrition are applicable across breeds and production systems and are described by books such as Larbier and Leclercq (1994). Feedstuffs and their evaluation are comprehensively covered by McNab and Boorman (2002).

ENERGY AND NUTRIENT REQUIREMENTS

Egg production requires the provision of the chemical components of the egg and also the energy required to convert these components into the substances deposited in the egg. Tables of nutrient requirements are produced by the feedstuffs and breeding industries and by organizations such as the National Research Council of the USA (NRC, 1994). Balnave (1974) calculated a 'net' efficiency of 61% for the conversion of feed energy to egg energy. However, the 'gross' efficiency (egg energy/total energy intake) is only about 20%. This is because most of the dietary energy consumed by the bird is used for 'maintenance', i.e. to sustain all the physiological and biochemical processes which keep the bird in a steady state. Maintenance energy requirement can be measured, either by calorimetry or by carcass analysis, as the energy intake which leads to zero energy balance.

Energy Cost of Activity

One component of the energy cost of egg production is that of any associated behaviour. Pre-oviposition behaviour increases heat production by about 60% over the resting value (MacLeod and Jewitt, 1985), similar to treadmill measurements of the cost of walking (van Kampen, 1976). The average duration of vigorous pre-laying activity (whether pre-laying restlessness in cages or nest investigation on litter) is only about 15 min (say 1% of the day) so would add only about 0.6% to the bird's daily energy expenditure. However, some birds begin to show less vigorous nest-oriented activity 1 h before oviposition, so the overall cost will be higher. Differences in activity contribute to between-breed differences in energy expenditure (e.g. between brown and white layers; MacLeod *et al.*, 1982) and can also be predicted to produce differences in energy requirements and food intakes between different housing systems. The activity of food intake has been shown to increase heat production by about 25% (MacLeod and Jewitt, 1985). There is a strong diurnal rhythm in the heat production of the laying hen (Berman and Meltzer, 1978; Lundy *et al.*, 1978; MacLeod *et al.*, 1988), with heat production at night usually being about 25% lower than in the light. Some, but not all, of the difference is due to activity (MacLeod *et al.*, 1982, 1988).

If the day–night difference is extrapolated simplistically, on the assumption that any additional hour of darkness has a similar effect, then each extra hour of

darkness should reduce heat production by about 1%. This has not been clearly detectable in short-term calorimetric studies (Riskowski *et al.*, 1977; MacLeod *et al.*, 1988) but estimates based on longer term measurements of food energy intake and body energy retention showed that 1-h increments in photoperiod gave increases similar to those predicted from chamber measurements (Lewis *et al.*, 1994).

FOOD AND NUTRIENT INTAKE

Quantitative Control of Intake

When laying hens are given a single compound diet, quantity of food eaten and time of eating are the only responses available to the bird. Under such conditions, food intake can only be a compromise among specific requirements for individual diet components. The requirements for energy and protein (or, more specifically, amino acids) are probably the strongest drivers of food intake. However, dietary energy concentration has the most influential effect under most conditions. Broadly speaking, this means that the intake of other nutrients in a compound diet will be inversely proportional to the energy concentration of the diet. Environmental factors which reduce energy intake (most commonly, an increased ambient temperature) will therefore reduce the intake of other components of the diet unless their concentrations are increased. Within a day, however, a temporal rhythm (e.g. in calcium requirement Hughes; 1972) may override or conflict with the requirement for other major nutrients. Over a broad range of ambient temperature (10–28°C), food intake declines as temperature increases. This is related to the lower heat production required to maintain body temperature. The quality of feather insulation (Tullett *et al.*, 1980) and stocking density (Savory and MacLeod, 1980) influence this relationship.

Qualitative Control of Intake

Free-choice feeding

Selecting among food sources so as to obtain the appropriate mixture of nutrients is of evolutionary advantage to birds living under natural conditions. A further refinement of this ability is to tune it to the bird's physiological state. That wild birds have this ability is clear from field and laboratory studies. For example, adult red grouse feed mainly on heather shoots but their chicks supplement this diet with invertebrates (mainly insects). The growth rate of grouse chicks is positively correlated with insect intake which is, in turn, correlated with insect abundance (Park *et al.*, 2001). The insect 'supplement' is clearly supplying a growth-limiting nutrient, which we can describe as protein but which can be narrowed down to individual amino acids. This ability to select among foods is of such fundamental evolutionary advantage that it seems unlikely to have been eliminated from domestic poultry by generations of breeding on compound diets. The persistence of this ability has been tested many times in poultry, with variable results (Hughes, 1984; Rose and Kyriazakis, 1991; Forbes and Covasa, 1995; Henuk and Dingle, 2002), although choice feeding was common practice before requirements had been sufficiently

well defined to allow the formulation of nutritionally complete diets. It might still be thought to have an advantage in allowing individual birds in a flock to select for their individual nutrient requirements, which may differ because of different rates of production, e.g. rate of lay (Emmans, 1977). However, factors other than an exact fit to metabolic and nutritional requirements are involved in diet selection and this may mean that free-choice feeding does not always give optimal production. These other factors include palatability, previous experience, social factors, and even trough position (Hughes, 1984).

Whole-grain feeding

Feeding whole grain as part of the diet has several potential advantages: it provides a form of environmental enrichment for the bird (Picard *et al.*, 2002), encourages muscular development of the gizzard and reduces feed processing costs. Grain (e.g. wheat, barley, oats) can be provided separately in a choice feeding system, mixed with mash or fed at alternating times to a compound diet (Rose *et al.*, 1995). Even with whole-grain feeding, particles entering the duodenum from the gizzard are both small and homogeneous, with 46–70% of particles being less than 100 μm in size (Hetland *et al.*, 2002). Starch digestibility is improved by the addition of whole wheat (Svihus and Hetland, 2001; Hetland *et al.*, 2002) and also by the inclusion of oat hulls (Hetland and Svihus, 2001). The gizzard has a well-developed ability to grind down larger particles such as whole grains, and increased gizzard size and activity may increase the opportunity for enzymatic digestion. However, not all whole-grain systems have given positive results (Bennett and Classen, 2003). Currently, whole-grain feeding is little used in the UK, although very coarse grinding may be used, leaving some whole grains in the feed. It should be noted that simply adding whole cereal grains 'on top of' an existing compound diet will dilute many nutrients and any positive effect of whole grain must, therefore, be sufficient to counterbalance the dilution effect.

Pellets or mash

Laying hen diets are usually fed in mash form. This may have the advantage of reducing feather pecking and other 'vices' (Aerni *et al.*, 2000). The most likely explanation is that feeding on mash is more time-consuming for the bird than eating pellets and also gives more opportunity for oral behaviour patterns. The negative side of this is that more energy is expended on mash feeding and there may also be more spillage, so the birds may show a slightly lower conversion efficiency (Savory, 1974). The process of pelleting usually involves a temperature increase, which may have beneficial effects; in experiments comparing pellets and mash it is therefore a good tactic to use re-ground pellets for the 'mash' treatments. Even when this precaution was taken, Savory (1974) found that growing layer chicks preferred mash and suggested that this may have been because they had to work harder to consume the same amount of food (Duncan and Hughes, 1972). This observation would now be termed 'contra-freeloading', which can be defined as a preference for earned food in the presence of free food and is interpreted as a form of information seeking (Inglis *et al.*, 1997; Lindqvist, 2002).

Specific Appetites

Calcium

A specific appetite for calcium is nowhere more clearly demonstrated than in the laying hen (Mongin and Sauveur, 1979). The effects of the onset of lay in the pullet (Meyer *et al*., 1970) and even the deposition of the individual eggshell (Hughes, 1972) are clearly detectable. Separate feeding of a calcium source is one form of free-choice feeding that is reliably successful. It has the advantage over feeding calcium only as part of a complete compound diet that the intake of calcium is dissociated from energy and protein intake and can occur at the time of maximum physiological demand. If the calcium source is given as part of a mash, using a larger particle size will facilitate active selection by the bird at times when calcium appetite is high. However, there is little evidence from commercial-scale trials that separate calcium provision is beneficial. Also, there is the practical problem that their high specific gravity may cause the separation of coarse calcium particles in mash diets, which carries the risk of deficiencies.

Amino acids

A slight deficiency of an amino acid in a compound diet has been shown to lead to a compensatory increase in food intake. Gross deficiency or excess, which can be summarized as an amino acid imbalance, usually leads to a reduction in intake (D'Mello, 1994). When offered a choice between a diet adequate in methionine and one 65% below adequate (Hughes, 1979), laying hens selected about 60% of total intake in the form of the adequate diet. This gave an egg production only slightly lower than in controls fed only on the methionine-adequate diet.

It is impossible to attempt comprehensive coverage of other specific appetites in this short chapter. Hughes (1979) reviewed requirements for zinc and thiamine. Zuberbuehler *et al*. (2002) found that selenium-deficient hens preferentially selected a high-selenium diet, presumably in response to post-ingestional feedback, since inadequate selenium, often in combination with low vitamin E status, causes deficiency symptoms in many species. Post-ingestional feedback is likely to be the key to most specific appetites. However, post-ingestional effects must become associated with an identifiable characteristic of the food – smell, taste, appearance, location – before the bird can learn to select for or against it.

NUTRITION FOR PRODUCTION

Egg Size and Number

Amino acids

Both number and size of eggs respond to the concentration of the first-limiting amino acid in the diet. Even if an amino acid is severely limiting, egg weight seldom falls below 90% of maximum, so any further response must be in rate of lay (Morris and Gous, 1988). Al-Saffar and Rose (2002) compiled the results from a large number of independent experiments to show that responses in both number and size could be approximated by an asymptotic exponential curve. The smooth response of whole-flock egg output to intake of an amino acid can be explained on the basis of individuals having an abrupt threshold response (at maintenance

intake) followed by a positive rectilinear response until a plateau response is abruptly attained. The smooth curve shown by the flock (Fig. 27.1) results from biological variation both in maintenance intake and in the intake for maximum response. Curnow (1973) derived an exact equation for the response line. Fisher *et al*. (1973) described a computer simulation method, using Monte Carlo random sampling techniques (see France and Thornley (1984) for a brief explanation) to simulate a flock. These models allow calculation of the financially optimal intake of an individual amino acid; this occurs where the gradient of the response curve is equal to the ratio of the cost of an additional unit of amino acid to the financial return from an additional unit of egg production. The gradient of the curve at any point can be calculated by differentiation. Above the optimum, the cost of extra amino acid provision exceeds the return from extra egg production. Curnow and Torenbeek (1996) explained how use of the model for an individual amino acid, assuming that other amino acids are not limiting production, can result in overestimation of optimum intakes. They proposed a model and optimization procedure which allows simultaneous estimation of the optimal intakes of several amino acids. The models summarized above deal explicitly with the fact that poultry nutritionists must often measure the response of a group rather than those of individuals.

Egg size can potentially be controlled by precise formulation on the first-

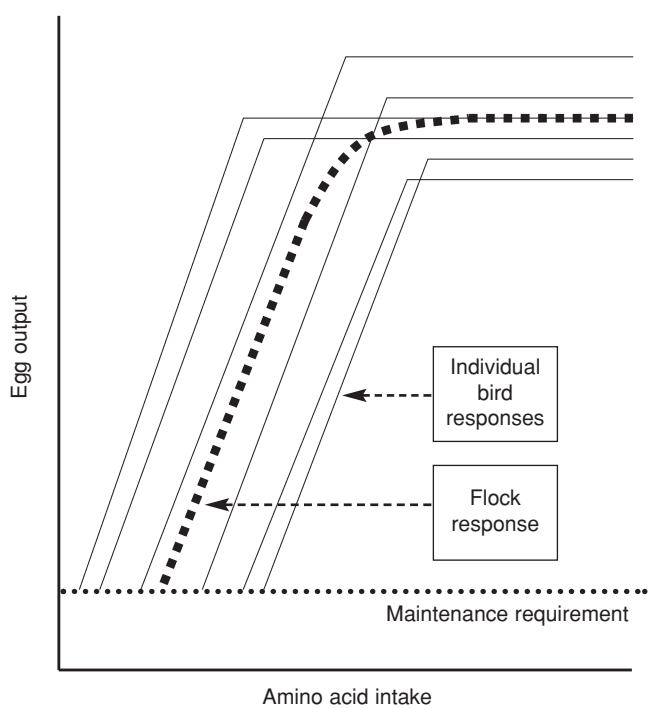

Fig. 27.1. A schematic diagram of how the asymptotic curvilinear response of flock egg output to intake of a limiting amino acid results from individuals having a threshold response (at maintenance intake) followed by a rectilinear response up to an abrupt plateau. The smooth whole-flock curve results from normal distributions of both maintenance intake and the intake for maximum response (Curnow, 1973; Fisher *et al*., 1973).

limiting amino acid (usually methionine+cystine, lysine or tryptophan). Precision can be reinforced by rapid feedback of data on food intake, production and egg size. The survey of Al-Saffar and Rose (2002) gave some support to the idea (Morris *et al.*, 1999) that amino acid concentrations are better described as proportions of dietary protein than as proportions of the entire diet.

Fatty acids

Linoleic acid (18:2*n*-6) and α-linolenic acid (18:3*n*-3) are recognized as essential fatty acids because they can not be synthesized by the bird. The requirement for α-linolenic acid has not been quantified but that of linoleic acid is usually given as about 10.0–11.5 g/kg of diet. Most research has shown a response in egg weight up to that concentration. In assessing the effect of linoleic acid on egg size, it is important to separate specific effects from the general effects of fat, which include its high metabolizable energy content and its positive effect on palatability. In experiments which have followed this rule, there has not usually been a specific effect of linoleic acid on egg size above 11.5 g/kg (Grobas *et al.*, 1999). A possible mechanism for egg size effects was demonstrated by Whitehead *et al.* (1993), who found that a diet high in linoleic acid resulted in elevated plasma oestradiol concentration. Oestradiol is known to regulate albumen synthesis in the oviduct, which relates to findings that egg weight increases in older hens occur mainly in the albumen.

Egg Quality

Calcium and phosphorus and shell quality

A clear difference between the starter and grower diets and those given during egg production is in the ratio of calcium to available phosphorus. This is about 2.0–2.5 in starter and grower diets and increases to almost 10.0 at peak production. The increased ratio is almost entirely due to increased calcium content, with phosphorus content remaining relatively constant. This is because the mineral component of eggshell is largely (98%) calcium carbonate, while that of bone is calcium phosphate. However, the dynamics of shell formation in relation to calcium intake and absorption are such that there may not always be sufficient blood calcium to satisfy demands. This leads to bone resorption to supply calcium and a consequent increase in circulating and excreted phosphorus (Miles *et al.*, 1984; Clunies and Leeson, 1994). Care must therefore be taken to provide sufficient dietary phosphorus to support bone replacement. However, an excess of dietary phosphorus leads to reduced eggshell thickness (Arscott *et al.*, 1962), possibly because a high plasma phosphate concentration inhibits bone mobilization (Miles and Harms, 1982).

Egg flavour

Rapeseed (in common with other *Brassica* species) contain glucosinolates, which affect thyroid and hepatic function (Bell, 1993). Although modern 'double zero' varieties have low contents of both glucosinolates and erucic acid, consumer codes in the UK currently prevent the use of rapeseed. Glucosinolates (thioglucosides) are enzymatically hydrolysed by myrosinase (thioglucidase) to yield compounds with antinutritional properties. These include isothiocyanates, thiocyanates, nitriles and

sulphur, depending on pH and other environmental factors. Varieties low in glucosinolates may still have a high sinapine content. This compound is degraded to trimethylamine, which produces a fishy taint in eggs, especially those of brown layers. These birds are genetically susceptible because they do not express the hepatic trimethylamine oxidase which would oxidize the compound producing the taint and should, therefore, be given diets with a low rapeseed meal content.

Yolk colour

Especially when diets are based on wheat or barley rather than maize, synthetic or concentrated xanthophyll supplements may be added to the feed to give the preferred intensity of yolk colour (Nys, 2000). The plant pigments are natural derivatives of β-carotene. They are present at high concentrations in marigold meal and some species of algae but are also present at practically useful concentrations in lucerne and grass meals.

Egg cleanliness

Eggs contaminated with droppings are often downgraded, causing a financial loss to the producer or incurring a cost for washing (currently not permitted for shell eggs in the UK). The incidence of dirty eggs is closely associated with the water content of the droppings and this, in turn, is strongly correlated with dietary sodium content (Smith *et al*., 2000). Also, one of the benefits of adding polysaccharidase enzymes to the diet is that they reduce the viscosity of the droppings, which contributes to egg cleanliness.

Nutrition According to Age

Phase feeding

From hatch to point-of-lay at 16–18 weeks of age, the birds will be on a sequence of starter and grower diets. A typical next step will be a 'pre-layer' diet until production is about 0.05 eggs/hen-day (5% production). The hens will then often be fed on a sequence of layer diets (e.g. Phase 1: 5% production – 27 weeks; Phase 2: 28–40 weeks; Phase 3: 41–59 weeks; Phase 4: week 60 onwards). These four example phases provide slightly different intakes of nutrients (particularly amino acids) corresponding with daily egg mass production. Using a single diet throughout lay would be costly, since the diet would have to be formulated to meet requirements at peak of lay. Feed programmes in the UK are now guided by feedback on feed intake and performance rather than by age. This has the advantage of allowing adjustment for ambient temperature.

NUTRITION FOR WELFARE

Bone Strength

The topic of skeletal disorders is covered elsewhere (Whitehead, this volume, Chapter 23). The main problem in layers is osteoporosis. This is caused by resorption of structural bone throughout the laying period. The process is largely under genetic and environmental control (Whitehead and Fleming, 2000) but

appropriate nutrition can help avoid excessive bone losses. The most obvious recommendation is to avoid deficiencies of calcium, phosphorus or vitamin D. This can include increasing the calcium content of the pre-layer diet to pre-empt the rapid increase in calcium demand at the onset of lay (Keshavarz, 1987). Providing a particulate calcium source may also be beneficial (Fleming *et al*., 1998). Larger particles (>0.8 mm) remain longer in the gizzard, which may lead to more efficient and longer-lasting absorption (Zhang and Coon, 1997) and may also permit selection by the bird even when incorporated in a mash diet. The withdrawal of feed several days before 'depopulation' of layer houses is to be avoided since it exacerbates bone loss at the very time when fracture risks are at their highest (Whitehead, 2002).

Nutrition and Heat Stress

Heat stress in layers is largely a problem in birds selected for high rates of production under temperate conditions. A high rate of egg production carries the penalty of higher metabolic heat production and the necessity to dissipate this heat to a warm or hot environment. 'Indigenous' poultry in tropical countries are closer in body shape and production rate to the ancestral jungle fowl. Their lower rate of production also fits them for a foraging lifestyle in which they do not compete with humans for high value, high protein and high energy foods. Where socio-economic conditions have encouraged intensive poultry farming in hot climates, environmental modification or control is usually the first recommendation. When this is not possible – or adequate – some nutritional strategies have been employed, often involving time of feeding or temporary feed withdrawal (MacLeod and Jewitt, 1984; Francis *et al*., 1990). Supplementation of the diet with vitamin E has been shown to alleviate the depression in egg production caused by high ambient temperature (Bollengier-Lee, 1999). There is also evidence that increased supplementation with vitamin A has beneficial effects on the immune system and egg production at high temperature (Lin *et al*., 2002). Vitamin C is not an essential nutrient for poultry under most conditions but does appear to alleviate heat stress (Pardue *et al*., 1985; Kutlu and Forbes, 1993).

Nutrient Effects on Behaviour

A high dietary concentration (20 g/kg) of tryptophan has been shown to reduce feather pecking in growing bantams, possibly because it is a precursor of 5-hydroxytryptamine (Savory *et al*., 1999). This was an uneconomically high concentration but there were signs of a dose-related response. A lower supplementation may therefore be beneficial but the effect may be difficult to detect except in larger experiments. Dietary tryptophan at lower concentrations has been shown to have a dose-dependent effect on brain 5-hydroxytryptamine, 5-hydroxyindoleacetic acid and norepinephrine in turkeys (Denbow *et al*., 1993). It has been asserted (Farm Animal Welfare Council, 1997) that the lack of animal protein in the diet makes pecking damage and 'cannibalism' more likely; this assertion has not been supported by controlled experiment (McKeegan *et al*., 2001).

NUTRITION FOR THE ENVIRONMENT

Ideal Protein

The contributions of the poultry industry to nitrogen pollution are determined by the feed, the bird and the interactions between the two. The best known dietary method of reducing nitrogenous waste is to use a protein composition (amino acid blend) which is closely matched to the bird's requirements (Meluzzi *et al*., 2001). This is often described as 'ideal protein'. The degree to which this is used in commercial practice is an economic (or legislative or consumer) matter because much is known about the relevant biology. As well as reducing nitrogen losses to the wider environment, it may improve bird welfare by reducing nitrogen excretion. This may improve floor and litter conditions in various husbandry systems and may also reduce ammonia concentration in the poultry house environment.

Phosphorus: Dietary Phytases

Much of the phosphorus in the plant ingredients of the hen's diet is incorporated in phytic acid and is relatively unavailable. Adding microbially produced phytase to the diet releases free phosphorus which the bird can use for many functions, including bone formation. The total amount of phosphorus in the diet can therefore be reduced, since a greater proportion is absorbed by the bird. Accordingly, less is expelled to become a potential pollutant, with phosphate being a major contributor to the eutrophication of inland waters. There are many examples of the successful use of microbial phytase. Lim *et al*. (2003) found that adding phytase to a diet slightly limited in available phosphorus improved egg production rate and decreased the incidence of broken and soft-shelled eggs. Depending on diet formulation, the amount of phosphorus expelled in the droppings can be reduced by more than 30% (Keshavarz, 2000). A further practical point for the feed formulator is that the reduced need for inorganic phosphorus (e.g. dicalcium phosphate) allows more 'space' for flexibility with other ingredients.

NUTRITION FOR CONSUMER REQUIREMENTS

Functional Foods

Given its function as the nutrient supply of the chick for its first 3 weeks of life, the nutritional properties of the egg are not in question. However, its composition can be manipulated, within limits, by alteration of the hen's diet (Noble, 1998). There have been recommendations that the ratio of *n*-3 to *n*-6 (sometimes termed omega-3 and omega-6) polyunsaturated fatty acids in the human diet should be increased to improve cardiovascular health. This can be achieved by increasing the proportion of oily fish in the human diet. However, the fatty acid profile of the egg can also be adjusted by including sources of *n*-3, which can be of animal (usually fish) or plant (e.g. linseed, rapeseed) origin. There are limits to the addition of fish oils and other long-chain *n*-3 sources because of the introduction of 'fishy' and other taints. Since many of the 'off' flavours are due to fatty acid oxidation, the

addition of antioxidants such as vitamin E is advisable (Leskanich and Noble, 1997). Fatty acids have been the usual targets for modification but there are many other possibilities. For instance, a 10 mg/kg dietary inclusion of folic acid increased the folate content of egg yolk from 17.5 to 41.0 μg/egg. One large egg from a folic acid-supplemented hen would provide about 12.5% of the recommended daily allowance (RDA) for adult humans (House *et al*., 2002). Iodine enrichment, using either potassium iodide or seaweed, has also been achieved and could supplement other sources in the human diet (Kaufmann *et al*., 1998).

Restrictions on Raw Materials

The feed formulator may be affected by legal or consumer-driven constraints on the use of certain raw materials. Current restrictions may include animal protein sources, genetically modified materials (GMO) and even synthetically produced amino acids. The latter two limitations apply particularly to 'organic' production. The longevity of such constraints is unknown but they must be considered where and when they exist. It is possible to formulate diets without animal protein, potential GMO (e.g. soybean and maize products) and synthetic amino acids, but it is difficult to attain all the nutritional optima. This may lead to performance below the birds' genetic potential. Hadorn *et al*. (2000) tested such diets and found significant effects on productivity, as would be predicted from nutritional theory. There was also a significant increase in mortality when synthetic amino acids were omitted. We can hypothesize that this may have been due to the importance of methionine in the immune system (Rama Rao *et al*., 2003). Also, the omission of sulphur-containing amino acids resulted in poorer plumage condition later in the laying period. Nitrogen excretion may be higher on 'vegetable protein' diets, if a larger amount of less-well-balanced protein has to be used to approach standard nutritional requirements (Hadorn *et al*., 2000). It would be unfortunate if a side-effect of organic or 'vegetable-protein-only' production was to increase nitrogen pollution.

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REFERENCES

Aerni, V., El-Lethey, H. and Wechsler, B. (2000) Effect of foraging material and food form on feather pecking in laying hens. *British Poultry Science* 41, 16–21.

Al-Saffar, A.A. and Rose, S.P. (2002) The response of laying hens to dietary amino acids. *World's Poultry Science Journal* 58, 209–234.

Arscott, G.H., Rachapaetayakom, P., Bernier, P.E. and Adams, F.W. (1962) The influence of ascorbic acid, calcium and phosphorus on specific gravity of eggs. *Poultry Science* 41, 485–488.

Balnave, D. (1974) Biological factors affecting energy expenditure. In: Morris, T.R. and Freeman, B.M. (eds) *Energy Requirements of Poultry*. British Poultry Science Ltd, Edinburgh, pp. 25–46.

Bell, J.M. (1993) Factors affecting the nutritional value of canola meal: a review. *Canadian Journal of Animal Science* 73, 679–697.

Bennett, C.D. and Classen, H.L. (2003) Performance of two strains of laying hens fed ground and whole barley with and without access to insoluble grit. *Poultry Science* 82, 147–149.

Berman, A. and Meltzer, A. (1978) Metabolic rate: its circadian rhythmicity in the female domestic fowl. *Journal of Physiology* 282, 419–427.

Bollengier-Lee, S. (1999) Optimal dietary concentration of vitamin E for alleviating the effect of heat stress on egg production in laying hens. *British Poultry Science* 40, 102–107.

Clunies, M. and Leeson, S. (1994) Calcium-45 dynamics of hens laying thick-shelled or thin-shelled eggs. *Canadian Journal of Animal Science* 74, 541–546.

Curnow, R.N. (1973) A smooth population response curve based on an abrupt threshold and plateau model for individuals. *Biometrics* 29, 1–10.

Curnow, R.N. and Torenbeek, R.V. (1996) Optimal diets for egg production. *British Poultry Science* 37, 373–382.

D'Mello, J.P.F. (1994). Amino acid imbalances, antagonisms and toxicities. In: D'Mello, J.P.F. (ed.) *Amino Acids in Farm Animal Nutrition*. CAB International, Wallingford, UK, pp. 63–97.

Denbow, D.M., Hobbs, F.C., Hulet, R.M., Graham, P.P. and Potter, L.M. (1993) Supplemental dietary L-tryptophan effects on growth, meat quality and brain catecholamine and indoleamine concentrations in turkeys. *British Poultry Science* 34, 715–724.

Duncan, I.J.H. and Hughes, B.O. (1972) Free and operant feeding in domestic fowl. *Animal Behaviour* 20, 775–777.

Emmans, G.C. (1977) The nutrient intake of laying hens given a choice of diets, in relation to their production requirements. *British Poultry Science* 18, 227–236.

Farm Animal Welfare Council (1997) *Report on the Welfare of Laying Hens*. Ministry of Agriculture, Fisheries and Food, HMSO, London.

Fisher, C., Morris, T.R. and Jennings, R.C. (1973) A model for the description and prediction of the response of laying hens to amino acid intake. *British Poultry Science* 14, 469–484.

Fleming, R.H., McCormack, H.A. and Whitehead, C.C. (1998) Bone structure and strength at different ages in laying hens and effects of dietary particulate limestone, vitamin K and ascorbic acid. *British Poultry Science* 39, 434–440.

Forbes, J.M. and Covasa, M. (1995) Application of diet selection by poultry with particular reference to whole cereals. *World's Poultry Science Journal* 51, 149–165.

France, J. and Thornley, J.H.M. (1984) *Mathematical Models in Agriculture*. Butterworths, London.

Francis, C.A., MacLeod, M.G. and Anderson, J.E.M. (1990) Alleviation of acute heat stress by food withdrawal or darkness. *British Poultry Science* 32, 219–225.

Grobas, S., Mendez, J., de Blas, C. and Mateos, G.G. (1999) Influence of dietary energy, supplemental fat and linoleic acid concentration on the performance of laying hens at two ages. *British Poultry Science* 40, 681–687.

Hadorn, R., Gloor, A. and Wiedmer, H. (2000) Einfluss des Ausschlusses von reinen Aminosäuren bzw. Potentiellen GVO-Eiweissträgern aus Legehennenfutter auf pflanzlicher Basis [Effect of the exclusion of synthetic amino acids and potentially

GMO-protein sources in vegetable diets for laying hens]. *Archiv für Geflügelkunde* 64, 75–81.

Henuk, Y.L. and Dingle, J.G. (2002) Practical and economic advantages of choice feeding systems for laying poultry. *World's Poultry Science Journal* 58, 199–208.

Hetland, H. and Svihus, B. (2001) Effect of oat hulls on performance, gut capacity and feed passage time in broiler chickens. *British Poultry Science* 42, 354–361.

Hetland, H., Svihus, B. and Olaisen, V. (2002) Effect of feeding whole cereals on performance, starch digestibility and duodenal particle size distribution in broiler chickens. *British Poultry Science* 43, 416–423.

House, J.D., Braun, K., Ballance, D.M., O'Connor, C.P. and Guenter, W. (2002) The enrichment of eggs with folic acid through supplementation of the laying hen diet. *Poultry Science* 81, 1332–1337.

Hughes, B.O. (1972) A circadian rhythm of calcium intake in the domestic fowl. *British Poultry Science* 13, 485–493.

Hughes, B.O. (1979) Appetites for specific nutrients. In: Boorman, K.N. and Freeman, B.M. (eds) *Food Intake Regulation in Poultry.* British Poultry Science Ltd, Edinburgh, pp. 141–169.

Hughes, B.O. (1984) The principles underlying choice feeding behaviour in fowls – with special reference to production experiments. *World's Poultry Science Journal* 40, 141–150.

Inglis, I.R., Forkman, B. and Lazarus, J. (1997) Free food or earned food: a review and fuzzy model of contrafreeloading. *Animal Behaviour* 53, 1171–1191.

Kaufmann, S., Wolfram, G., Delange, F. and Rambeck, W.A. (1998) Iodine supplementation of laying hen feed: a supplementary measure to eliminate iodine deficiency in humans? *Zeitschrift für Ernahrungswissenschaft* 37, 288–293.

Keshavarz, K. (1987) Influence of feeding a high calcium diet for various durations in prelaying period on growth and subsequent performance of White Leghorn pullets. *Poultry Science* 66, 1576–1582.

Keshavarz, K. (2000) Nonphytate phosphorus requirement of laying hens with and without phytase on a phase feeding program. *Poultry Science* 79, 748–763.

Kutlu, H.R. and Forbes, J.M. (1993) Changes in growth and blood parameters in heat-stressed broiler chicks in response to dietary ascorbic acid. *Livestock Production Science* 36, 335–350.

Larbier, M. and Leclercq, B. (1994) *Nutrition and Feeding of Poultry* (translated into English by J. Wiseman). Nottingham University Press, Nottingham.

Leskanich, C.O. and Noble, R.C. (1997) Manipulation of the *n*-3 polyunsaturated fatty acid composition of avian eggs and meat. *World's Poultry Science Journal* 53, 155–183.

Lewis, P.D., MacLeod, M.G. and Perry, G.C. (1994) Effects of lighting regime and grower diet energy concentration on the energy expenditure, fat deposition and body weight gain of laying hens. *British Poultry Science* 35, 407–415.

Lim, H.S., Namkung, H. and Paik, I.K. (2003) Effects of phytase supplementation on the performance, egg quality, and phosphorus excretion of laying hens fed different levels of dietary calcium and nonphytate phosphorus. *Poultry Science* 82, 92–99.

Lin, H., Wang, L.F., Song, J.L., Xie, Y.M. and Yang, Q.M. (2002) Effect of dietary supplemental levels of vitamin A on the egg production and immune responses of heat-stressed laying hens. *Poultry Science* 81, 458–465.

Lindqvist, C.E.S., Schutz, K.E. and Jensen, P. (2002) Red jungle fowl have more contrafreeloading than white leghorn layers: effect of food deprivation and consequences for information gain. *Behaviour* 139, 1195–1209.

Lundy, H., MacLeod, M.G. and Jewitt, T.R (1978) An automated multi-calorimeter system: preliminary experiments on laying hens. *British Poultry Science* 19, 173–186.

MacLeod, M.G. and Jewitt, T.R. (1984) Circadian variation in the heat production rate of the domestic fowl (*Gallus domesticus*): effects of limiting feeding to a single daily meal. *Comparative Biochemistry and Physiology* 78A, 687–690.

MacLeod, M.G. and Jewitt, T.R. (1985) The energy cost of some behavioural patterns in laying domestic fowl: simultaneous calorimetric, Doppler-radar and visual observations. *Proceedings of the Nutrition Society* 44, 34A.

MacLeod, M.G., Jewitt, T.R., White, J., Verbrugge, M. and Mitchell, M.A. (1982) The contribution of locomotor activity to energy expenditure in the domestic fowl. In: Ekern, A. and Sundstol, E. (eds) *Energy Metabolism of Farm Animals*: *Proceedings of the 9th EAAP Symposium,* Lillehammer. Department of Animal Nutrition, Agricultural University of Norway, Aas, pp. 297–300.

MacLeod, M.G., Jewitt, T.R. and Anderson, J.E.M. (1988) Energy expenditure and physical activity in domestic fowl kept on standard and interrupted lighting patterns. *British Poultry Science* 29, 231–244.

McKeegan, D.E.F., Savory, C.J., MacLeod, M.G. and Mitchell, M.A. (2001) Development of pecking damage in layer pullets in relation to dietary protein source. *British Poultry Science* 42, 33–42.

McNab, J.M. and Boorman, K.N. (eds) (2002) *Poultry Feedstuffs: Supply, Composition and Nutritive Value. Poultry Science Symposium Series,* Vol. 26. CAB International, Wallingford, UK.

Meluzzi, A., Sirri, F., Tallarico, N. and Franchini, A. (2001) Nitrogen retention and performance of brown laying hens on diets with different protein content and constant concentration of amino acids and energy. *British Poultry Science* 42, 213–217.

Meyer, G.B., Babcock, S.W. and Sunde, M.L. (1970) Decreased feed consumption and increased calcium intake associated with the pullet's first egg. *Poultry Science* 49, 1164–1169.

Miles, R.D. and Harms, R.H. (1982) Relationship between egg specific gravity and plasma phosphorus from hens fed different dietary calcium, phosphorus and sodium levels. *Poultry Science* 61, 175–177.

Miles, R.D., Junqueira, O.M. and Harms, R.H. (1984) Plasma phosphorus at 0, 6 and 21 hours postoviposition in hens laying in the morning or afternoon. *Poultry Science* 63, 354–359.

Mongin, P. and Sauveur, B. (1979) The specific calcium appetite of the domestic fowl. In: Boorman, K.N. and Freeman, B.M. (eds) *Food Intake Regulation in Poultry.* British Poultry Science Ltd, Edinburgh, pp. 171–189.

Morris, T.R. and Gous, R.M. (1988) Partitioning of the response to protein between egg number and egg weight. *British Poultry Science* 29, 93–99.

Morris, T.R., Gous, R.M. and Fisher, C. (1999) An analysis of the hypothesis that amino acid requirements for chicks should be stated as a proportion of dietary protein. *World's Poultry Science Journal* 55, 7–22.

Noble, R.C. (1998) Manipulation of the nutritional value of eggs. In: Garnsworthy, P.C. and Wiseman, J. (eds) *Recent Advances in Animal Nutrition.* Nottingham University Press, Nottingham, pp. 49–66.

NRC (National Research Council) (1994) *Nutrient Requirements of Poultry*, 9th rev. edn. National Academy Press, Washington, DC.

Nys, Y. (2000) Dietary carotenoids and egg yolk coloration: a review. *Archiv für Geflügelkunde* 64, 45–54.

Pardue, S.L., Thaxton, J.P. and Brake, J. (1985) Role of ascorbic acid in chicks exposed to high environmental temperature. *Journal of Applied Physiology* 58, 1511–1516.

Park, K.J., Robertson, P.A., Campbell, S.T., Foster, R., Russell, Z.M., Newborn, D. and Hudson, P.J. (2001) The role of invertebrates in the diet, growth and survival of red grouse (*Lagopus lagopus scoticus*) chicks. *Journal of Zoology* 254, 137–145.

Picard, M., Melcion, J.P., Bertrand, D. and Faure, J.M. (2002) Visual and tactile cues perceived by chickens. In: McNab, J.M. and Boorman, K.N. (eds) *Poultry Feedstuffs: Supply, Composition and Nutritive Value. Poultry Science Symposium Series,* Vol. 26. CAB International, Wallingford, UK, pp. 279–300.

Rama Rao, S.V., Praharaj, N.K., Reddy, M.R. and Panda, A.K. (2003) Interaction between genotype and dietary concentrations of methionine for immune function in commercial broilers. *British Poultry Science* 44, 104–112.

Riskowski, G.L., De Shazer, J.A. and Mather, F.B. (1977) Heat losses of White Leghorn laying hens as affected by intermittent lighting schedules. *Transactions of the ASAE* 20, 727–731.

Rose, S.P. and Kyriazakis, I. (1991) Diet selection of pigs and poultry. *Proceedings of the Nutrition Society* 50, 87–98.

Rose, S.P., Fielden, M., Foote, W.R. and Gardin, P. (1995) Sequential feeding of whole wheat to growing broiler chickens. *British Poultry Science* 36, 97–111.

Savory, C.J. (1974) Growth and behaviour of chicks fed on pellets or mash. *British Poultry Science* 15, 281–286.

Savory, C.J. and MacLeod, M.G. (1980) Effects of grouping and isolation on feeding, food conversion and energy expenditure of domestic chicks. *Behavioural Processes* 5, 187–200.

Savory, C.J., Mann, J.S. and MacLeod, M.G. (1999) Incidence of pecking damage in growing bantams in relation to food form, group size, stocking density, dietary tryptophan concentration and dietary protein source. *British Poultry Science* 40, 579–584.

Smith, A., Rose, S.P., Wells, R.G. and Pirgozliev, V. (2000) The effect of changing the excreta moisture of caged laying hens on the excreta and microbial contamination of their egg shells. *British Poultry Science* 41, 168–173.

Svihus, B. and Hetland, H. (2001) Ileal starch digestibility in growing broiler chickens fed a wheat-based diet is improved by mash feeding, dilution with cellulose or whole wheat inclusion. *British Poultry Science* 42, 633–637.

Tullett, S.G., MacLeod, M.G. and Jewitt, T.R. (1980) The effects of partial defeathering on energy metabolism in the laying fowl. *British Poultry Science* 21, 241–245.

van Kampen, M. (1976) Activity and energy expenditure in laying hens. 2. The energy cost of exercise. *Journal of Agricultural Science* 87, 81–84.

Whitehead, C.C. (2002) Nutrition and poultry welfare. *World's Poultry Science Journal* 58, 349–356.

Whitehead, C.C. and Fleming, R.H. (2000) Osteoporosis in caged layers. *Poultry Science* 79, 1033–1041.

Whitehead, C.C., Bowman, A.S. and Griffin, H.D. (1993) Regulation of plasma oestrogen by dietary fats in the laying hen: relationships with egg weight. *British Poultry Science* 34, 999–1010.

Zhang, B.F. and Coon, C.N. (1997) The relationship of calcium intake, source, size, solubility *in vitro* and *in vivo*, and gizzard limestone retention in laying hens. *Poultry Science* 76, 1702–1706.

Zuberbuehler, C.A., Messikommer, R.E. and Wenk, C. (2002) Choice feeding of selenium-deficient laying hens affects diet selection, selenium intake and body weight. *Journal of Nutrition* 132, 3411–3417.

CHAPTER 28
Human–animal interactions

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ABSTRACT

Research in a number of livestock industries has shown that interactions between stockpeople and their animals can limit the welfare of the animals. While these interactions may appear harmless to the animals, this research has shown that the frequent use of some of these routine behaviours by stockpeople can result in farm animals becoming highly fearful of humans. It is these high fear levels, through stress, that appear to limit animal welfare and productivity. This research has also shown that one of the main antecedents of stockperson behaviour is the attitude of the stockperson towards interacting with his or her animals.

These relationships between human and animal variables indicate the opportunity to target stockperson attitudes and behaviour in order to improve animal welfare. Intervention studies in the dairy and pig industries have shown the potential of cognitive-behavioural intervention techniques designed to specifically target those key attitudes and behaviours of stockpeople that have a direct effect on animal fear, productivity and welfare. Recent studies in the pig industry indicate that other job-related characteristics, such as empathy and attitudes towards aspects of work, are useful predictors of work performance of the stockperson and, thus, suggest that such measures could be used to assist in selecting stockpeople.

While this research on human–animal interactions in the livestock industries has mainly focused on the dairy and pig industries, there has been some limited research conducted on meat chickens and laying hens. This latter research has generally supported the results of research on human–animal interactions in the dairy and pig industries and indicates that the interactions between stockpeople and their birds can limit the welfare and productivity of commercial poultry.

Therefore, it is proposed that these relationships between human and animal variables provide an excellent opportunity to target stockperson attitudes and behaviour in order to reduce limitations imposed by human–animal interactions on poultry welfare. Understanding stockperson behaviour appears to be the key to manipulating these human–animal interactions to improve poultry welfare. An improved understanding of the effects of routine behaviours used by stockpeople on the bird's fear of humans is necessary to reduce the effects of fear on bird welfare. This is particularly important because some of these interactions identified to date are not intuitively obvious. Furthermore, the attitudes underpinning these human interactions will also only be identified through rigorous research examining stockperson attitude–behaviour relationships.

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While housing clearly affects animal welfare, the lack of recognition of the critical role of the stockperson has probably hindered efforts to attract, train and retain competent stockpeople and, in turn, improve the welfare of intensively managed livestock. There is a clear requirement for widespread and increased recognition and appreciation of the important role of the stockperson on farm animal welfare. Appropriate strategies to recruit and train stockpeople in the egg industry will be integral in safeguarding the welfare of commercial laying hens in the future.

INTRODUCTION

With increasing intensification of livestock production, the dependency of livestock on the stockperson to effectively care and manage them correspondingly increases. While all forms of livestock production rely to varying degrees on key inputs from the stockperson, this reliance is arguably greater with increased confinement of the animal. Automation may relieve the stockperson of some duties, but Hemsworth and Coleman (1998) have argued that automation is unlikely, in the foreseeable future, to completely replace the stockperson. An essential role of stockpeople in achieving high animal performance and welfare is the careful observation of the animals under their care. Although animal conditions such as ambient temperature, noxious gas levels and presence of feed and water can be remotely monitored, direct and careful observation of the animals often provides the first evidence of departure from normality. In particular, behavioural change can be used by stockpeople to identify abnormality, such as illness or stress, and thus prompt identification of an impending problem for the animal relies heavily on the careful observation by the stockperson of the animal's behaviour. Clearly, automation should be utilized to assist the stockperson in monitoring animals and their conditions, and automation of the more tedious and laborious tasks, such as cleaning, provision of feed and water and control of the thermal environment, may free up the stockperson to concentrate on those tasks that require more rigorous observation, knowledge and skill, such as detecting and promptly attending to or seeking advice on problem animals. While not necessarily a legal requirement, codes of practice for farm animals in many countries often state that the daily observation of animals in confined conditions is essential.

Human–animal interactions are a common feature of intensive livestock production. In egg production, stockpeople and hens are in regular and, at times, close contact and there may be several levels of interaction between stockpeople and their birds. Many of these interactions are associated with regular observation of the hens and their conditions and these interactions often involve only visual contact between the stockperson and the hens. Tactile interactions, together with visual and auditory interactions, may be used by stockpeople in catching and moving birds before or after the period of lay and in situations in which birds must be restrained and subjected to management or health procedures such as beak trimming and vaccinations.

Human–animal relationships can be considered to be constructed from a series of interactions between humans and animals (Hemsworth *et al.*, 1992). The nature of the interactions by a human towards an animal may be positive, neutral or negative for the animal. For example, fear-provoking interactions such as the sudden unexpected appearance of a human or a human looming over an animal

may be negative for the animal, while painful interactions such as a vaccination or capture are obviously negative to animals. It is the nature of these human interactions that will markedly determine the quality of the human–animal relationship for the animal. The quality of the relationship for the animal can be assessed by measuring the approach behaviour or conversely the avoidance behaviour of the animal to the human in a standard testing situation (Hemsworth and Coleman, 1998). The relationships that exist between humans and farm animals in intensive livestock production are true relationships in that the interactions are frequent and often intense and, more importantly as considered later, the interactions can have reciprocal effects on the partners.

The aim of this chapter is to review the impact of these human–animal interactions on the welfare of commercial laying hens and consider some of the opportunities that exist to reduce the limitations that some of these interactions may impose on hen welfare.

THE ROLE OF THE STOCKPERSON

The key characteristic of any employee, irrespective of the industry in which he or she works, is how well he or she does the job. Blumberg and Pringle (1982) have proposed a model of work performance that identifies three classes of contributing factors: *capacity*, *opportunity* and *willingness* to do the job (see Fig. 28.1). When considering the work performance of the stockperson in a livestock industry, *capacity* will include variables such as technical skills and knowledge, and attitude and behaviour towards the animals, while *willingness* includes motivation, job

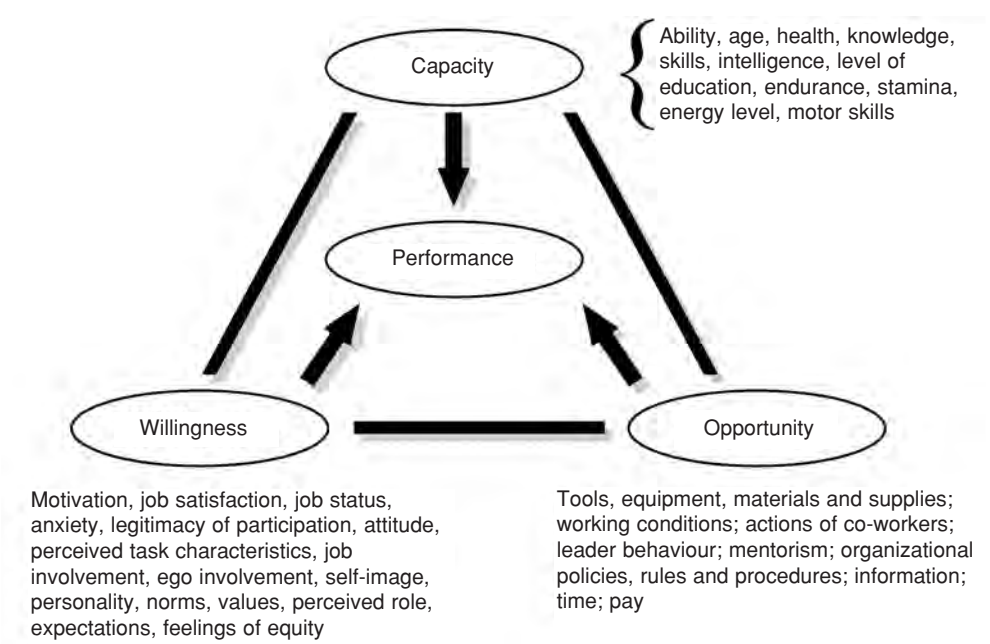

Fig. 28.1. A model of work performance (adapted from Blumberg and Pringle, 1982).

satisfaction and work attitude, and *opportunity* includes working conditions and facilities, actions of co-workers and organizational policies and rules. Hemsworth and Coleman (1998) have considered in some detail the impact of these variables on the welfare and productivity of livestock and some of these job-related variables of the stockperson will be considered here because of their impact on animal welfare.

Research conducted in the livestock industries has shown that human interactions can have surprising effects on the animal (Hemsworth and Coleman, 1998). While many of these interactions may appear mild and harmless to the animals, research has shown that the frequent use of some routine behaviours by stockpeople can result in farm animals becoming highly fearful of humans. There is evidence that these high fear levels, through stress, will limit animal welfare and productivity. This research has also shown that a major antecedent of stockperson behaviour is the attitude of the stockperson towards interacting with his or her animals. A model of these human–animal relationships in the intensive livestock industries is presented in Fig. 28.2 and the regulation and impact of these interactions on the welfare of laying hens will be discussed in more detail later in this chapter.

There are a number of other important human characteristics that are likely to affect the welfare of laying hens, such as technical skills and knowledge, job motivation and commitment and job satisfaction of the stockperson (Hemsworth and Coleman, 1998). While the impact of these other characteristics may be more obvious, they have been less thoroughly researched in the livestock industries than the impact of the stockperson's attitudes and behaviour.

One of single most important factors in job performance is the technical skills and knowledge that the person brings to the job (Hemsworth and Coleman, 1998). Knowing and being skilled at the techniques that must be used to accomplish the task are clearly prerequisites to being able to perform that task. Although there is a lack of empirical data on this topic in the agricultural industries, this basic premise is generally well accepted. These job-related characteristics are therefore likely to be the most limiting factors to job performance in the egg industry in situations where specific technical skills and knowledge (e.g. recognition of failure to thrive in birds) are required to perform the tasks.

Work motivation in the livestock industries generally refers to the extent to which a person applies his or her skills and knowledge to the management of the

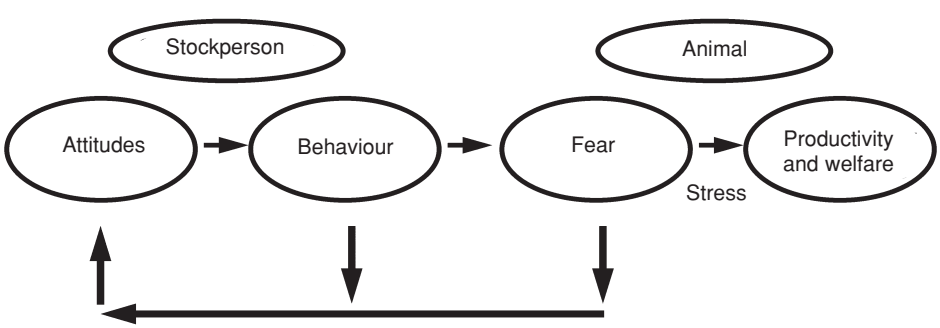

Fig. 28.2. A simple model of human–animal relationships in the intensive livestock industries.

animals under his or her care (Hemsworth and Coleman, 1998). Therefore, work motivation is the degree to which the stockperson is reliable, thorough and conscientious in managing his or her animals. High job performance in any industry relies on a combination of motivation, technical knowledge and skills and an opportunity to perform the job, and clearly low motivation will limit job performance regardless of technical skills and knowledge of the individual. That is, the stockperson must be motivated in order to achieve high standards of animal welfare in his or her animals.

Job satisfaction refers to the extent to which a person reacts favourably or unfavourably to his or her work and is believed to derive from the extent to which a person's needs or expectations are being met by the job (Hemsworth and Coleman, 1998). Job satisfaction of the stockperson is likely to affect animal welfare because of its direct effects on other job-related characteristics such as job motivation and commitment, motivation to learn new skills and knowledge and thus, in turn, technical skills and knowledge. Hemsworth and Coleman (1998) and Coleman (2003) have reviewed some of the personal and job factors that affect both work motivation and job satisfaction, but without sufficient empirical data to either demonstrate their impact on work performance or the effectiveness of strategies to improve these job-related characteristics in stockpeople.

Human–animal interactions may also influence a number of these job-related variables and thus affect the work performance of the stockperson. For instance, a poor attitude to interacting with animals, by affecting ease of handling, may influence the stockperson to the extent that job-related characteristics, such as job satisfaction and work motivation and commitment, may be affected, with implications for the job performance of the stockperson. Coleman *et al*. (1998) found that attitudes towards pigs and towards most aspects of working with pigs were correlated with a number of measures of work motivation in stockpeople. Attitudes showed similar relationships with job enjoyment and opinions about working conditions. Thus, the stockperson's attitudes may be related to aspects of work apart from handling of animals, and these influences may impact on animal welfare.

A personality trait is widely considered to be a relatively enduring characteristic which exerts a general effect on that person's behaviour and which cannot be observed directly, but can be inferred from the person's behaviour (Coleman, 2003). Most researchers agree that personality can be characterized in terms of the 'big five' personality traits: 'extraversion/introversion'; 'emotional stability'; 'agreeableness'; 'conscientiousness'; and 'intellect' (Barrick and Mount, 1991). It is also generally well accepted that personality factors may be useful in matching people to some kinds of jobs (Barrick and Mount, 1991). For example, discipline and conformity may be important factors in some jobs in which routine tasks are performed by teams of people, while independence, introversion and self-motivation may be important in others in which the tasks are more problematic and where the individual may at times work alone. Indeed Ravel *et al*. (1996), in studying stockpeople in the pig industry, found that the relationships between the personality of the stockperson and piglet mortality varied according to the working place. While self-discipline was a trait that appeared to be important at all farms studied, high insecurity and low sensitivity were favourable traits in relation to piglet survival at small independent owner-operated farms, while stockpeople who were highly reserved and bold, suspicious, tense and changeable were associated with higher piglet mortality at larger integrated farms.

In studies of stockpeople at dairy and pig farms, Seabrook (1972, 1991) reported that some personality traits were associated with animal productivity. In contrast, Waiblinger *et al*. (2002) found that personality factors were not significantly correlated with animal productivity at dairy farms. However, Waiblinger *et al*. (2002) found that some personality factors were significantly correlated with the attitudes of stockpeople towards their cows. Coleman *et al*. (2000a) and Coleman (2001), in a study of stockpeople entering the pig industry, also found no consistent relationships between personality factors and job performance.

Empathy is another factor that may influence the work performance of stockpeople. Empathy can be described as the capacity to put oneself in the place of another (Hemsworth and Coleman, 1998), and Coleman (2003) has proposed that stockpeople are likely to perform better if they have a good insight into the emotional responses of the animals under their care. Beveridge (1996) found that empathy towards animals was positively associated with positive attitudes towards interacting with cows and positive beliefs about cows, but was not directly associated with a stockperson's behaviour towards cows. Coleman *et al*. (1998) found that empathy towards animals was associated with positive beliefs about pigs and about handling pigs and Coleman *et al*. (2000a) and Coleman (2001) found that empathy was associated with positive behaviour towards pigs as well as a high level of intention to remain working in the pig industry. These findings suggest that empathy may be a factor underlying the development of positive attitudes towards farm animals.

While there is little evidence in the livestock industries relating personality and empathy directly to the work performance of the stockperson, Hemsworth and Coleman (1998) and Coleman (2003) have proposed that these characteristics may indirectly affect animal welfare and productivity by influencing the development of the attitudes of the stockpeople to their animals. The antecedents of attitudes are many and varied and Hemsworth and Coleman (1998) have discussed in detail the development of attitudes. Demographic variables, various general attitudes and personality traits may indirectly affect behaviour through their influence on attitudes and, while the important dispositional factor in predicting the behaviour of the stockperson is attitude, other dispositional factors, including personality and empathy, may operate indirectly through attitudes.

Therefore, while not well studied in the livestock industries, factors such as technical skills and knowledge, job motivation and commitment and job satisfaction of the stockperson are likely to affect the welfare of laying hens. Human–animal interactions, which are primarily influenced by the attitude of the stockperson towards his or her animals, can markedly affect the welfare of farm animals and the next section discusses in detail the development of these human–animal interactions and their impact on the welfare of laying hens.

THE EFFECTS OF STOCKPERSON BEHAVIOUR ON BIRD FEAR AND WELFARE

Immediate Causation

Fear is generally considered an undesirable emotional state of suffering in both humans and animals (Jones and Waddington, 1992). Studies in the dairy and pig

industries have consistently shown negative fear–productivity relationships (Hemsworth *et al*., 1981, 1989; Breuer *et al*., 2000); high levels of fear of humans, assessed on the approach behaviour of animals to humans, were correlated with reduced animal productivity. Handling studies on dairy cows and pigs not only support the results of these studies in the livestock industries but also indicate that a high level of fear of humans through stress is the likely mechanism whereby fear of humans depresses the productivity of commercial livestock (see Hemsworth and Coleman (1998) for details of these studies).

Studies in the dairy and pig industries have also shown significant sequential relationships between the stockperson's attitudes and behaviour towards animals and the fear of humans and productivity of dairy cows and pigs (Hemsworth *et al*., 1989, 2000; Coleman *et al*., 1998; Breuer *et al*., 2000). This research indicates that the attitude of the stockperson towards interacting with his or her animals is a key antecedent of the behaviour of the stockperson and that the behaviour of the stockperson towards his or her animals is an important determinant of the animal's fear of humans. The existence and importance of these sequential relationships is demonstrated in intervention studies in the dairy and pig industries in which cognitive-behavioural training of stockpeople, designed to specifically improve these key attitudes and behaviours of stockpeople, decreased animal fear and improved animal productivity and welfare (Hemsworth *et al*., 1994a, 2002; Coleman *et al*., 2000b).

Less research has been conducted in the poultry industries on human–animal interactions. Studies by Barnett *et al*. (1992), Hemsworth *et al*. (1994b, 1996) and Cransberg *et al*. (2000) found significant negative relationships, based on farm averages, between the level of fear of humans and the productivity of commercial meat chickens and laying hens. The egg production of laying hens at the farm was inversely related to the level of fear of humans by birds at the farm (Barnett *et al*., 1992) and the efficiency of feed conversion of meat chickens was inversely related to the level of fear of humans by birds at the farm (Hemsworth *et al*., 1994b, 1996). Similarly, in an experiment examining the effects of cage position on fear and egg production of laying hens, level of fear of humans was significantly and negatively related to egg production and efficiency of feed conversion (Hemsworth and Barnett, 1989). In observations on the behavioural response of laying hens to an experimenter, Bredbacka (1988) reported that egg mass production was lower in hens that showed increased avoidance of humans.

Handling studies on poultry also generally indicate that handling treatments likely to increase the birds' fear of humans may depress the growth performance of chickens. For example, in experiments with young chickens, Gross and Siegel (1979, 1980, 1982) found that birds that received frequent human contact of an apparent positive nature, such as gentle touching, talking and offering food on the hand, from an early age had improved growth rates and feed efficiency and were more resistant to infection than birds that either received minimal human contact or had been deliberately scared. Deliberate scaring, in the third treatment, involved shouting and banging on the birds' cages. Although the behavioural response of the birds to humans was not quantified, the authors stated that the previously handled birds were easier to handle during weighing and blood sampling than the other birds. Barnett *et al*. (1994) found that regular visual contact, involving positive elements such as slow and deliberate movements, which reduced the subsequent avoidance behaviour of adult laying hens, resulted in higher egg production

than a treatment which involved minimal human contact. The authors speculated that the lower productivity of birds in the latter treatment may be a consequence of a chronic stress response, since there was evidence of immunosuppression in these highly fearful birds.

Hemsworth and Coleman (1998) have proposed that a farm animal's response to a stockperson in an intensive livestock system may have components of both stimulus-specific fear and general fear. Thus, while the initial response of a naive bird to humans may involve a response to novelty or unfamiliarity (i.e. general fearfulness), a specific response to humans is likely to develop with subsequent experience of humans. This initial response to humans may be similar to the bird's response to an unfamiliar object or to unfamiliar animals of another species. Furthermore, as suggested by Suarez and Gallup (1985), the predominant response of naive domestic poultry to humans may be a response to a predator. The original relationship between humans and the ancestors of domestic poultry was a predator–prey relationship (Duncan, 1990) and, as shown by Desforges and Wood-Gush (1975), domestication has reduced but not eliminated the magnitude of the bird's initial fear response to humans.

As a consequence of the amount and nature of interactions with humans, commercial poultry are likely to develop a stimulus-specific response to humans. Murphy and Duncan (1977, 1978) studied two lines of chickens, termed 'flighty' and 'docile' on the basis of their behavioural responses to humans, and found that early handling affected the behavioural responses of these two lines of birds to humans, with the docile birds showing a more rapid reduction in their withdrawal responses to humans with regular exposure to humans than the flighty birds. These line differences may be stimulus-specific, since observations indicated that the docile birds did not necessarily show less withdrawal response to novel stimuli, such as a mechanical scraper and an inflating balloon, than the flighty birds (Murphy, 1976; Jones *et al*., 1991). Jones and Waddington (1992) studied the effects of regular handling on the behavioural responses of quail and domestic chickens to novel stimuli (such as a blue light) and humans and found that handling predominantly affected the responses of birds to humans, rather than to the novel stimuli. Handled birds showed reduced avoidance of humans but their responses to novel stimuli were unaffected. These data indicate that prior experience with humans results in stimulus-specific effects rather than effects on general fearfulness.

Therefore, although there will be some components of novelty in the response of experienced farm animals to humans, which will occur with changes in the stimulus property of humans, such as changes in behaviour, clothing and location of interaction, a major component of this response is likely to be experientially determined. Chickens and laying hens are particularly sensitive to visual contact with humans. The regular imposition of treatments involving the experimenter placing his/her hand either on or in the chicken's cage and allowing birds to observe other birds being handled has been shown to result in reductions in the subsequent avoidance of humans shown by young chickens (Jones, 1993). Interestingly, visual contact without tactile contact was more effective in reducing fear than picking up and stroking the bird, suggesting that this tactile handling by humans may contain aversive elements for birds such as active interaction and tactile interaction. Hemsworth *et al*. (1994b) examined the effects of regular close visual contact with humans on the fear responses of young chickens to humans. At 6 weeks of age, birds that had received regular human contact showed less avoidance of an

approaching experimenter and had lower corticosterone concentrations after handling than birds that had received minimal human contact. A handling study on adult laying hens by Barnett *et al*. (1994) also clearly demonstrates the influential effects of visual contact with humans on fear responses of birds to humans. Regular visual contact with humans, involving positive elements such as slow and deliberate movements by the experimenter, markedly reduced the subsequent avoidance behaviour of mature laying hens to humans in comparison with minimal contact that at times contained elements of sudden and unexpected human contact. The birds that had received regular visual contact with humans also had lower corticosterone concentrations following handling than the birds that had only minimal human contact.

A number of handling studies on poultry have made use of handling treatments involving stroking and/or carrying birds, and these have generally been imposed on young chickens of both meat and egg-production strains. Although some of the tactile components of the handling treatments may contain negative elements, such as stroking birds, many of these treatments often resulted in birds displaying reduced avoidance of humans (Hughes and Black, 1976; Murphy and Duncan, 1978; Jones and Faure, 1981). Habituation of the bird's fear responses over time with repeated exposure to humans is likely to be responsible for these observed reductions in fear of humans. Hughes and Black (1976) and Murphy and Duncan (1977) found little or no effects on avoidance behaviour of birds to humans if handling was imposed on adult birds, while Barnett *et al*. (1994) found that increased human contact, predominantly involving visual contact, reduced the subsequent avoidance responses of adult laying hens.

Hemsworth *et al*. (1996) and Cransberg *et al*. (2000) reported that broiler chickens were most fearful of humans at farms in which stockpeople moved quickly and frequently made a noise by tapping on objects as they moved through the poultry facility. Surprisingly, frequency of waving by the stockperson was not negatively associated with avoidance of the experimenter by the birds. It is possible that waving by the stockperson, which intuitively appears to be fear-provoking, may simply reflect a behaviour by the stockperson necessitated by non-fearful birds remaining closer to the stockperson as he/she moves slowly through the poultry facility.

Therefore, laying hens placed in situations in which they frequently interact with humans may, through conditioning, associate humans with rewarding and punishing events that occur at the time of these interactions and thus conditioned responses to humans may develop. Furthermore, habituation may occur over time as the hens' fear of humans is gradually reduced by repeated exposure to humans in a neutral context; that is, the human's presence has neither rewarding nor punishing elements. Poultry appear to be particularly sensitive to visual contact with humans, and indeed positive visual contact, such as slow and deliberate movement, may be more effective in reducing levels of fear of humans than human tactile contact. Relatively little is known of the negative visual interactions from humans that may elevate fear levels in poultry; however, rapid speed of movement by humans and sudden and unexpected exposure to the humans may be fear-provoking.

Ontogenic Effects

The extensive studies by John Paul Scott (see Scott, 1992) on the effects of early human contact on the socialization of dogs to humans clearly reveal the long-term effects of early human contact on the subsequent behavioural responses of dogs to humans. There is similar evidence in some farm animal species that the age of the animal when handling first occurs is influential in reducing subsequent fear responses to humans, and this topic is well reviewed by Rushen *et al*. (2001). Early handling has persistent effects on fear of humans in cattle, horses, pigs, sheep and silver foxes (e.g. Waring, 1983; Boissy and Bouissou, 1988; Lyons *et al*., 1988; Lyons, 1989; Pedersen and Jeppesen, 1990; Hemsworth and Barnett, 1992; Pedersen, 1993; Markowitz *et al*., 1998; Krohn *et al*., 2001). A number of studies have shown that rearing young animals either artificially or with their dams does not appear to affect the influence of early human contact on subsequent fear responses to humans (see Rushen *et al*., 2001).

Breed differences in the behavioural response to humans have been reported for chickens (Craig *et al*., 1983; Craig and Muir, 1989) and sheep (Roumeyer and Bouissou, 1992). Hemsworth *et al*. (1990) found that the behavioural response of relatively naive pigs to humans was moderately heritable. However, since the pigs were relatively inexperienced with humans, the authors may have been mainly measuring the heritability of general fearfulness, since subsequent experience with humans markedly affected the behavioural response of these pigs. As discussed earlier, a farm animal's response to a stockperson may have components of both stimulus-specific fear and general fear. Thus, while the initial response of a naive animal to humans may involve a response to novelty or unfamiliarity (i.e. general fearfulness), a specific response to humans is likely to develop with subsequent experience of humans.

Therefore, while the behavioural response of farm animals to humans may be moderately heritable, the response is heavily influenced by the animal's experiences with humans. Habituation and conditioning are important learning mechanisms in affecting the fear response to humans, but early human contact may have long-lasting effects.

OPPORTUNITIES TO IMPROVE BIRD WELFARE BY IMPROVING THE WORK PERFORMANCE OF STOCKPEOPLE

The sequential relationships between stockperson attitude and behaviour and animal fear and productivity that have been found in the dairy and pig industries (Hemsworth *et al*., 1989, 2000; Coleman *et al*., 1998; Breuer *et al*., 2000) demonstrate the opportunities that may exist to improve animal welfare by appropriate selection and training of stockpeople. Studies in the dairy and pig industries have shown that it is possible to improve the attitudinal and behavioural profiles of stockpeople and, in turn, to reduce the level of fear and improve the productivity of commercial cows and pigs (Hemsworth *et al*., 1994a, 2002; Coleman *et al*., 2000b). Recent results by Coleman *et al*. (2000a) and Coleman (2001) indicate that job-related characteristics such as empathy, attitudes towards animals and towards aspects of work are useful predictors of the work performance of the stockperson and, thus, potentially such measures could be assembled into a kit for use in selection of stockpeople in the pig industry.

Empirical data from the poultry industries on the relationships between the job-related characteristics of stockpeople and animal welfare and productivity are not as substantial. Barnett *et al*. (1992), Hemsworth *et al*. (1994b, 1996) and Cransberg *et al*. (2000) found significant negative fear–productivity relationships at broiler and egg farms and Hemsworth *et al*. (1996) and Cransberg *et al*. (2000) found significant relationships between stockperson behaviour and bird fear at broiler farms. The opportunities to reduce fear of humans and thus the limitations imposed by human–animal interactions on poultry welfare and productivity ultimately rely on identifying and targeting the key attitudes and behaviour of stockpeople that regulate these fear responses in birds. Cransberg *et al*. (2000) found no evidence of a relationship between stockperson attitude and behaviour in the broiler industry, but the range of attitudinal variables targeted in the study may not have been sufficiently extensive. An improved understanding of the effects of routine behaviours used by stockpeople on the bird's fear of humans is necessary to reduce the effects of fear on bird welfare. This is particularly important because some of these interactions identified to date are not intuitively obvious. Furthermore, the attitudes underpinning these human interactions will also only be identified through rigorous research examining stockperson attitude–behaviour relationships.

CONCLUSIONS

Research in the livestock industries, including the egg industry, indicates that human–animal interactions can markedly limit animal welfare and productivity. The sequential relationships between human and animal variables found in the dairy and pig industries indicate that there may be an excellent opportunity to target stockperson attitudes and behaviour in order to reduce limitations imposed by human–animal interactions on poultry welfare. Understanding stockperson behaviour appears to be the key to manipulating these human–animal interactions to improve poultry welfare. Appropriate strategies to recruit and train stockpeople in the egg industry will be integral in safeguarding the welfare of commercial laying hens in the future.

Hemsworth and Barnett (2004), in reviewing the effects of housing and the stockperson on the welfare of intensively managed livestock, make the point that within the livestock industries, the general community and, to a lesser extent, the scientific community, human factors are generally considered to have a relatively minor influence on animal welfare. While housing clearly affects animal welfare, the lack of recognition of the critical role of the stockperson has probably hindered efforts to attract, train and retain competent stockpeople and, in turn, to improve animal welfare. There is a clear requirement for widespread and increased recognition and appreciation of the important role of the stockperson in farm animal welfare.

REFERENCES

Barnett, J.L., Hemsworth, P.H. and Newman, E.A. (1992) Fear of humans and its relationships with productivity in laying hens at commercial farms. *British Poultry Science* 33, 699–710.

Barnett, J.L., Hemsworth, P.H., Hennessy, D.P., McCallum, T.M. and Newman, E.A. (1994) The effects of modifying the amount of human contact on the behavioural, physiological and production responses of laying hens. *Applied Animal Behaviour Science* 41, 87–100.

Barrick, M.P. and Mount, M. (1991) The big five personality dimensions and job performance: a meta-analysis. *Personnel Psychology* 44, 1–26.

Beveridge, L.M. (1996) Studies on the influence of human characteristics and training on stockperson work performance and farm animal behaviour. PhD thesis, University of Aberdeen, UK.

Blumberg, M. and Pringle, C.D. (1982) The missing opportunity in organisational research: some implications for a theory of work performance. *Academy of Management Review* 7, 560–569.

Boissy, A. and Bouissou, M.F. (1988) Effects of early handling on heifers' subsequent reactivity to humans and to unfamiliar situations. *Applied Animal Behaviour Science* 20, 259–273.

Bredbacka, P. (1988) Relationships between fear, welfare and productive traits in caged White Leghorn hens. In: Unshelm, J., Van Putten, G., Zeeb, K. and Ekesbo, I. (eds) *Proceedings of the International Congress on Applied Ethology in Farm Animals*, *Skara.* Kuratorium für Technik und Bauen in der Landwirtschaft (KTBL), Darmstadt, Germany, pp. 74–89.

Breuer, K., Hemsworth, P.H., Barnett, J.L., Matthews, L.R. and Coleman, G.J. (2000) Behavioural response to humans and the productivity of commercial dairy cows. *Applied Animal Behaviour Science* 66, 273–288.

Coleman, G.J. (2001) Selection of stockpeople to improve productivity. In: *The 4th Industrial and Organisational Psychology Conference, Sydney, 21–24 June.*

Coleman, G.J. (2003) Personnel management in agricultural systems. In: Rollin, B.E. and Benson, J. (eds) *Maximizing Well-being and Minimizing Suffering in Farm Animals*. Iowa State University Press, Iowa.

Coleman, G.J., Hemsworth, P.H., Hay, M. and Cox, M. (1998) Predicting stockperson behaviour towards pigs from attitudinal and job-related variables and empathy. *Applied Animal Behaviour Science* 58, 63–75.

Coleman, G.J., Hall, M., Fewings-Hall, S. and Hemsworth, P.H. (2000a) Selection of stockpeople in the pig industry. *Final Report to the Pig Research and Development Corporation*, Project UMO 5/1139.

Coleman, G.J., Hemsworth, P.H., Hay, M. and Cox, M. (2000b) Modifying stockperson attitudes and behaviour towards pigs at a large commercial farm. *Applied Animal Behaviour Science* 66, 11–20.

Craig, J.V. and Muir, W.M. (1989) Fearful and associated responses of caged White Leghorn hens: genetic parameter estimates. *Poultry Science* 68, 1040–1046.

Craig, J.V., Craig, T.P. and Dayton, A.D. (1983) Fearful behaviour by caged hens of two genetic stocks. *Applied Animal Ethology* 10, 263–273.

Cransberg, P.H., Hemsworth, P.H. and Coleman, G.J. (2000) Human factors affecting the behaviour and productivity of commercial broiler chickens. *British Poultry Science* 41, 272–279.

Desforges, M.F. and Wood-Gush, D.G.M. (1975) A behavioural comparison of domestic and mallard ducks: habituation and flight reactions. *Animal Behaviour* 23, 692–697.

Duncan, I.J.H. (1990) Reactions of poultry to humans. In: Zayan, R. and Dantzer, R. (eds) *Social Stress in Domestic Animals*. Martinus Nijhoff, The Hague, pp. 121–130.

Gross, W.B. and Siegel, P.B. (1979) Adaptation of chickens to their handlers and experimental results. *Avian Diseases* 23, 708–714.

Gross, W.B. and Siegel, P.B. (1980) Effects of early environmental stresses on chicken body weight, antibody response to RBC antigens, feed efficiency and response to fasting. *Avian Diseases* 24, 549–579.

Gross, W.B. and Siegel, P.B. (1982) Influences of sequences of environmental factors on the responses of chickens to fasting and to *Staphylococcus aureus* infection. *American Journal of Veterinary Research* 43, 137–139.

Hemsworth, P.H. and Barnett, J.L. (1989) Relationships between fear of humans, productivity and cage position of laying hens. *British Poultry Science* 30, 505–518.

Hemsworth, P.H. and Barnett, J.L. (1992) The effects of early contact with humans on the subsequent level of fear of humans in pigs. *Applied Animal Behaviour Science* 35, 83–90.

Hemsworth, P.H. and Barnett, J.L. (2004) On-farm handling and environments: impact on animal welfare. *Applied Animal Behaviour Science* 85.

Hemsworth, P.H. and Coleman, G.J. (1998) *Human–Livestock Interactions: The Stockperson and the Productivity and Welfare of Intensively-farmed Animals*. CAB International, Wallingford, UK.

Hemsworth, P.H., Brand, A. and Willems, P.J. (1981) The behavioural response of sows to the presence of human beings and their productivity. *Livestock Production Science* 8, 67–74.

Hemsworth, P.H., Barnett, J.L., Coleman, G.J. and Hansen, C. (1989) A study of the relationships between the attitudinal and behavioural profiles of stockpersons and the level of fear of humans and reproductive performance of commercial pigs. *Applied Animal Behaviour Science* 23, 301–314.

Hemsworth, P.H., Barnett, J.L., Treacy, D. and Madgwick, P. (1990) The heritability of the trait fear of humans and the association between this trait and subsequent reproductive performance of gilts. *Applied Animal Behaviour Science* 25, 85–95.

Hemsworth, P.H., Barnett, J.L. and Coleman, G J. (1992) Fear of humans and its consequences for the domestic pig. In: Davis, H. and Balfour, D. (eds) *The Inevitable Bond: Examining Scientist–Animal Interactions*. Cambridge University Press, Cambridge, pp. 264–284.

Hemsworth, P.H., Coleman, G.J. and Barnett, J.L. (1994a) Improving the attitude and behaviour of stockpersons towards pigs and the consequences on the behaviour and reproductive performance of commercial pigs. *Applied Animal Behaviour Science* 39, 349–362.

Hemsworth, P.H., Coleman, G.J., Barnett, J.L. and Jones, R.B. (1994b) Fear of humans and the productivity of commercial broiler chickens. *Applied Animal Behaviour Science* 41, 101–114.

Hemsworth, P.H., Coleman, G.C., Cransberg, P.H. and Barnett, J.L. (1996) Human factors and the productivity and welfare of commercial broiler chickens. *Research Report on Chicken Meat Research and Development Council Project*, Attwood, Australia.

Hemsworth, P.H. Coleman, G.J., Barnett, J.L. and Borg, S. (2000) Relationships between human-animal interactions and productivity of commercial dairy cows. *Journal of Animal Science* 78, 2821–2831.

Hemsworth, P.H., Coleman, G.J., Barnett, J.L., Borg, S. and Dowling, S. (2002) The effects of cognitive behavioral intervention on the attitude and behavior of stockpersons and the behavior and productivity of commercial dairy cows. *Journal of Animal Science* 80, 68–78.

Hughes, B.O. and Black, A.J. (1976) The influence of handling on egg production, egg shell quality and avoidance behaviour of hens. *British Poultry Science* 17, 135–144.

Jones, R.B. (1993) Reduction of the domestic chick's fear of humans by regular handling and related treatments. *Animal Behaviour* 46, 991–998.

Jones, R.B. and Faure, J.M. (1981) The effects of regular handling on fear responses in the domestic chick. *Behavioural Processes* 6, 135–143.

Jones, R.B. and Waddington, D. (1992) Modification of fear in domestic chicks, *Gallus gallus domesticus* via regular handling and early environmental enrichment. *Animal Behaviour* 43, 1021–1033.

Jones, R.B., Mills, A.D. and Faure, J.M. (1991) Genetic and experimental manipulation of fear-related behaviour in Japanese quail chicks (*Coturnix coturnix japonica*). *Journal of Comparative Psychology* 105, 15–24.

Krohn, C.G., Jago, J.G. and Boivin, X. (2001) The effect of early handling on the socialisation of young calves to humans. *Applied Animal Behaviour Science* 74, 121–133.

Lyons, D.M. (1989) Individual differences in temperament of dairy goats and the inhibition of milk ejection. *Applied Animal Behaviour Science* 22, 269–282.

Lyons, D.M., Price, E.D. and Moberg, G.P. (1988) Individual differences in temperament of domestic dairy goats: constancy and change. *Animal Behaviour* 36, 1323–1333.

Markowitz, T.M., Dally, M.R., Gursky, K. and Price, E.O. (1998) Early handling increases lamb affinity for humans. *Animal Behaviour* 55, 187–195.

Murphy, L.B. (1976) A study of the behavioural expression of fear and exploration in two stocks of domestic fowl. PhD dissertation, Edinburgh University, UK.

Murphy, L.B. and Duncan, I.J.H. (1977) Attempts to modify the responses of domestic fowl towards human beings. I. The association of human contact with a food reward. *Applied Animal Ethology* 3, 321–334.

Murphy, L.B. and Duncan, I.J.H. (1978) Attempts to modify the responses of domestic fowl towards human beings. II. The effect of early experience. *Applied Animal Ethology* 4, 5–12.

Pedersen, V. (1993) Effects of difference post-weaning handling procedures on the later behaviour of silver foxes. *Applied Animal Behaviour Science* 37, 239–250.

Pedersen, V. and Jeppsen, L.L. (1990) Effects of early handling on better behaviour and stress responses in the silver fox (*Vulpes vulpes*). *Applied Animal Behaviour Science* 26, 383–393.

Ravel, A., D'Allaire, S.D. and Bigras-Poulin, M. (1996) Associations between preweaning performance and management, housing, personality of the stockperson on independent and integrated swine farms in Quebec. In: *Proceedings of the 14th Congress of the International Pig Veterinary Society, 7–10 July, Bologna, Italy*. Faculty of Veterinary Medicine, University of Bologna, Bologna, Italy.

Roumeyer, A. and Bouissou, M.F. (1992) Assessment of fear reactions in domestic sheep and the influence of breed and rearing conditions. *Applied Animal Behaviour Science* 34, 93–119.

Rushen, J., de Passille, A.M.B., Munksgaard, L. and Tanida, H. (2001) People as social actors in the world of animals. In: Keeling, L.J. and Gonyou, H.W. (eds) *Social Behaviour in Farm Animals.* CAB International, Wallingford, UK, pp. 353–372.

Scott, J.P. (1992) The phenomenon of attachment in human–non human relationships. In: Davis, H. and Balfour, A.D. (eds) *The Inevitable Bond: Examining Scientist–Animal Interactions*. Cambridge University Press, Cambridge, pp. 72–92.

Seabrook, M.F. (1972) A study to determine the influence of the herdsman's personality on milk yield. *Journal of Agricultural Labour Science* 1, 45–59.

Seabrook, M.F. (1991) The influence of the personality of the stockperson on the behaviour of pigs. *Applied Animal Behaviour Science* 30, 187 (Abstract).

Suarez, S.D. and Gallup, G.G. Jr (1985) Predatory overtones of open-field testing in chickens. *Animal Learning and Behaviour* 9, 155–163.

Waiblinger, S., Menke, C. and Coleman, G. (2002) The relationship between attitudes, personal characteristics and behaviour of stockpeople and subsequent behaviour and production of dairy cows. *Applied Animal Behaviour Science* 79, 195–219.

Waring, G.H. (1983) *Horse Behavior: The Behavioral Traits and Adaptations of Domestic and Wild Horses, Including Ponies*. Noyes Publications, Park Ridge, New Jersey.

CHAPTER 29
Handling and catching of hens during depopulation

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ABSTRACT

At depopulation, many commercially grown end-of-lay hens are subjected to welfare insults. Many of these insults result in stress or fear, which are difficult to quantify, but newly fractured bones leave a permanent record that can be quantified. This chapter summarizes the prospects for various systems that could be adopted by the industry in order to reduce the welfare insults. The methods discussed include modifying bird behaviour, eliminating the depopulation of live birds, mechanized handling, and minimal manual handling. This chapter also discusses the design of housing systems and how this might affect depopulation. It is concluded that, to encourage a quick uptake by the industry, any new system would have to be simple, low-cost, and capable of being used with existing housing systems, transport arrangements and processing facilities, while not compromising biosecurity. A promising method involves manual catching using wheeled modular drawers positioned close to the hens. This system allows individual hens to be placed directly into the drawers, so minimizing human contact. Subsequent handling is of the filled modules and hence, in this respect, the hen's welfare is protected.

INTRODUCTION

In 2002, the UK layer flock produced over 10,000 million eggs, and during this period 32 million hens were slaughtered (DEFRA, 2003). The majority of hens (approximately 72%) are kept in battery cages, even though there has been a move towards alternative housing systems such as barn (5%) and free-range (23%) systems since the mid-1980s (NFU, 2003).

During stocking, the point-of-lay pullet is, physiologically speaking, relatively robust. This, combined with the intrinsically high value of the point-of-lay pullets and the associated handling, means that the birds are unlikely to experience severe welfare insults. However, at depopulation several factors, including the low value of the birds, combine to make a welfare insult more likely and, compared with pop-

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ulating, more difficult to prevent. Indeed farmers may have to pay to have these birds removed. The hens almost invariably suffer from osteoporosis (Knowles and Broom, 1990) caused by lack of exercise and the demands made on the hen's skeleton by eggshell production (Gregory and Wilkins, 1992). The subsequent reduced bone strength leads to considerable numbers of birds sustaining fractures during depopulation. For example, Gregory and Wilkins (1989) found that an average of 24% had new fractures after being removed from the cages and carried to the transport crates at the end of the shed, but the same authors showed that with careful handling of individual hens, the bone breakage could be reduced to 14%. A later survey by Gregory *et al*. (1994) showed an improvement, with 14% of birds being found with new broken bones at the point of stun in the UK (16.5% average for three European countries). This was assumed to be due to improved awareness of the problem and hence greater care being taken. All of these values were for similar manual depopulation methods, although small improvements in cage design may also have had an effect. These data indicate that the practice then was similar to the best that could be achieved without a radical change to the depopulation method. It is unlikely that current methods will be much improved, given the low value of the hens and the difficulty in recruiting quality labour for such an unpleasant task (Scott and Moran, 1993).

It is obvious that the welfare of injured birds has been impaired, and counting those with broken bones can quantify an extreme aspect of the problem. However, it is likely that even uninjured birds will suffer varying degrees of stress. Duncan (1990) and Hansen *et al*. (1993) presented evidence that the dominant reactions of poultry to human beings are fearful, and Freeman (1984) lists handling, inversion and crating among the potential stressors. Duncan (1989) found evidence of elevated heart rate and corticosterone concentrations in broilers in response to manual catching and restraint. The stressor effects of such contact were so pronounced that inversion of the birds, or deliberate rough treatment, had no additional effect. Kannan and Mench (1996), also with broilers, found that the handling method did not influence corticosterone levels of crated birds, 'either because crating is a more potent stressor than handling or due to stressor additivity'.

The amount of damage to the hens can vary. Gregory and Wilkins (1992) reported that 53% of birds in one sample had fractures. However, the same study also found samples with no broken bones. They concluded that this does 'offer some encouragement' as 'by understanding the causes of this variation there should be ample opportunity for improving the overall situation'. Broom (1990) stated that there are two principal ways to reduce the proportion of hens suffering from bones fractured during depopulation and these are: (i) to increase bone strength; and (ii) to reduce the amount of handling by catchers. Whitehead and Fleming (2000) have shown that there is scope to increase bone strength through genetic manipulation, but this chapter focuses on the practical aspects of catching and handling techniques.

Currently, all end-of-lay hens are caught and placed into transport crates by hand. Any manual handling of hens will compromise their welfare. Duncan (1989) reported that a bird's heart rate increased by about 70 beats per minute when approached by the catcher and 100 beats/min when lifted. If the birds were then carried upright the heart rate started to drop, but if inverted the heart rate remained high. Kannan and Mench (1997) also showed that corticosterone levels in broilers are highest immediately after handling. Kannan and Mench (1996,

1997) also showed that upright handling of broilers was less stressful than inverted handling.

Almost irrespective of the type of housing system, commercial depopulation in the UK uses solely manual handling and consists of:

- initial catching of a single hen in cages or multiple birds if loose-housed, but all held by both legs;
- inverting the hens and carrying them along the poultry house;
- transferring the hens on to the transport vehicle;
- loading the hens into the transport container.

The container may be the 'traditional' plastic crate 85 × 66 × 30 cm, known as a loose crate, with an opening some 30 × 32 cm on the top for the birds to be put through, generally more than one at a time. However, at least one major egg producer is using the module system produced by Anglia Autoflow for broilers (L. Craig, Buckinghamshire, personal communication). This module has the advantage of a large opening to put the birds in but, because of its large size, it cannot be taken close to the birds so there is still considerable carrying of inverted birds. During the depopulation process the hens are usually passed from hand to hand several times. Typically the catcher passes them to the carrier who passes them on to a loader to be put in the transport container. Using the loose crates, there will often be two other handlings of birds, to and from 'holders' at the building exit and again on the lorry.

The purpose of this chapter is to discuss the scope for, and constraints on, specifying an improved yet practical system to depopulate hens.

HOUSING SYSTEMS

A brief description of housing systems is given as background for the discussion which follows.

Battery Cages

A typical cage layer unit usually has several houses, each containing a flock of many thousands of hens. Up to six hens are kept in a cage. The cages are arranged in tiered rows along the length of the house with access passageways between them. The passageways are the only routes for bringing in the point-of-lay pullets and removing the hens at about 75 weeks of age. The floor of the house may be raised 3 m or more above ground level to facilitate handling of the manure. However, this can make the handling of the pullets and hens more difficult, as they have to be lifted and lowered between the lorry, the ground and the house floor. Some modern houses now have a platform outside the house at lorry floor level to help reduce, but not eliminate, the lifting and lowering problems.

The *Welfare of Farmed Animals Regulations* (DEFRA, 2002a) not only specifies minimum standards for cages and alternative systems but, of relevance to this chapter, states that:

> the design and dimensions of the cage door must be such that an adult hen can be removed without undergoing unnecessary suffering or sustaining injury

and that

> to facilitate … depopulation of hens there must be a minimum aisle width of 90 cm between tiers and a space of at least 35 cm must be allowed between the floor of the building and the bottom tier of cages.

In order to maintain the advantages of cages but to alleviate the problems associated with poor bird welfare, there are enriched cage designs that incorporate features that have been found from research to offer welfare improvements. Enriched cages differ from conventional cages in a number of respects, but most notably they provide the bird with more useable space (600 cm^2 versus 550 cm^2/hen), a nest, litter and perches. However, in terms of depopulation, it should be noted that the minimum aisle width between cages is no greater than that for conventional cages. Also the impact of furniture within cages on the welfare of the bird at depopulation has yet to be systematically assessed.

Barn system

Barn systems exist in two main forms: those with a flat floor and those with layers of perches (known as aviaries or percheries). The aviary type makes maximum use of the vertical space within the poultry house. At least one nestbox should be provided for every seven hens and 15 cm of perch for each hen housed. The minimum horizontal distance between perches should be 30 cm and, specifically for aviaries, while there should be no more than four tiers, the minimum distance between levels is 45 cm. This configuration can make depopulation difficult and unpleasant for the catching crew, with the birds being able to move away from the catchers across and under the furniture if care is not taken.

It is notable, however, that observations by Fleming *et al*. (1994) have shown that end-of-lay hens from barn-type systems can have stronger bones than those from cage systems; bone strength is affected by many factors, including the weight loading upon the bone.

Free-range

In order to meet the requirements for free-range production, hens are kept in units not dissimilar to those used for barn systems, with popholes allowing access to open ground, but with the popholes closed at night. Normally, for the purposes of depopulation, the birds are housed in the unit with the popholes closed. However, a few trials have been carried out using a Walker 25 turkey transport module placed outside the popholes which have then been opened and the hens, habituated to go outside, go straight into the module unit (P. Frost, Norfolk, personal communication). The Walker 25 is a single-layer module with a drop-down side and lift-up cover, developed so that turkeys could walk in for transport to the processing plant. It performed well in comparative catching and crating trials with turkeys (Prescott *et al*., 2000).

Discussion of Housing Systems

There appears to be no housing system that offers any significant advantage for depopulation. So-called extensive housing such as free-range and barn are difficult to depopulate since the hens can move away from the catchers. This creates dust and noise, and makes the other hens agitated and more prone to flight, so compounding the difficulties. Timed doors to control the movements of the hens at certain times of the day could be used in preparation for depopulating in order to minimize the space that is available to hens in certain designs of barn systems.

Cages constrain the hens so that they can be readily caught, yet the depopulation of birds from this system may be associated with a relatively high incidence of bone fractures. It is important to ensure that future cage designs and battery housing, and aviary, perchery and free-range layouts address the problem of careful handling of hens both at population and at depopulation.

CONVENTIONAL DEPOPULATION

Within the industry, end-of-lay hens may be known as 'spent hens', reinforcing the perception of a waste product which is not conducive to good handling of live birds. Gregory and Wilkins (1992) observed various catching methods for depopulating end-of-lay hens from cages. The most common method at the time was to use one hand to remove individual hens from the cage by one leg and transfer them to the other hand until the required number had been removed from the cage. Hens were then passed back into the catching hand until equal numbers were held in each hand, still by one leg. Another method observed was to catch up to three hens by one leg with one hand, remove them from the cage together, and then pass them to the other hand. The hens, once caught, were carried, suspended by one leg, out of the house to the transport vehicle and, for loose crates, lifted and pushed into relatively small openings. In contrast to the practices reported by Gregory and Wilkins (1992), the current DEFRA *Code of Recommendations for the Welfare of Livestock: Laying Hens* (2002b) recommends the following when catching hens:

- remove sharp edges and hindrances;
- take care to avoid panic by, for example, reducing light levels or using blue light;
- competent people, appropriately trained, should handle the birds;
- birds in cages … must be removed from the cage singly and, to avoid injury or suffering, they must be held by BOTH legs and the breast should also be supported;
- loose-housed birds must be caught and held by BOTH legs to avoid injury or suffering.

This is clearly a considerable advance on the methods recorded by Gregory and Wilkins in 1992.

These recommendations (DEFRA, 2002b) are informed by experimental results such as those that demonstrated that the incidence of bone breakages was reduced significantly when birds were caught by two legs, rather than by one, although there was little difference between removing hens in groups or one at a time (Gregory and Wilkins, 1992). The use of a breast support over the feed

trough has been investigated but showed little improvement in the number of broken bones and slowed the catching process (Gregory *et al*., 1992).

It is notable, however, that a later study by Gregory *et al*. (1994) indicated that the incidence of broken bones had reduced greatly when compared with the data presented 2 years previously. It was not known why this should be, but the authors suggested that greater awareness of the problem resulted in more care being taken by the catchers when depopulating hens. Also, improvements to cage design, particularly of the door opening, may have made it easier for the catching crew to remove birds from the cages.

POTENTIAL ALTERNATIVE DEPOPULATION METHODS

System Design Objectives

Depopulation involves the following phases: establish control of the hens by physical restraint or other means; transfer the hens to a transport mechanism; transport the hens close to a vehicle outside the building; transfer the hens from the transport mechanism; and control the hens while they are placed into the road transport container.

Arguably, if it is to be commercially viable, any new system should meet as many of the following criteria as possible:

- improve the welfare of the hen both during depopulation and during handling at shackling;
- not compromise the health and safety of people using the system;
- be capable of use for population and depopulation;
- be compatible with existing crate/module handling and unloading systems on lorries and especially at the processing plant;
- be quick, obvious and easy to set up, dismantle, transport and handle;
- be quiet in operation;
- be usable with the majority of, and preferably all, existing housing systems;
- should incorporate appropriate fail-safe systems;
- match, or improve upon, existing hen handling rates;
- be easy to maintain, wash and disinfect;
- be economically viable.

Modifying Behaviour to Aid Depopulation

These methods aim to modify behavioural responses of hens to encourage them to move as required and to habituate them to the depopulation process.

Specific stimuli

Physical stimuli which the birds find aversive, such as air blasts or water jets, could be adapted to move hens from one area to another, or to ensure that they are standing up when required to do so. Other stimuli that could be aversive include vision, odour, sound, electric shocks, mechanical pushing, vibration, and hot or cold air. However, birds often exhibit inconsistent innate reactions, as described by

Bolles (1970). Highly fearful birds, for example, show a freezing response to aversive or novel stimuli (Jones, 1982).

Attractive stimuli might also be used to draw birds from one area to another. For example, appetitive behaviour is characterized by high levels of locomotory and exploratory behaviour which will enhance the probability of a bird finding food (Savory *et al.,* 1992; Wechsler, 1995). Theoretically, by concentrating feeding in a particular area, depopulation of birds could be achieved rapidly. However, in practice, this apparently attractive solution has a number of potential problems, as birds will consequently have full crops at the processing plant, which may be a problem to the processor. Another problem is that the greater areas of empty space created by depopulation may elicit fear and the birds may migrate away from the feeding area. Similarly, the entrance of stockmen to the system may also disperse birds from the feeding area. Hens in cages, for example, tend to react adversely to approaching humans (Jones *et al*., 1981) and the effect is heightened in birds which see humans less often (Jones, 1985).

Habituating procedures

Habituation may be described as the progressive decrease in responsiveness resulting from the repeated presentation of a stimulus (Thompson and Spencer, 1966). This process could be exploited, since hens adapt quickly to specific features of their environment which initially caused them disturbance. Broom (1986) showed that hens that most avoided human contact when in their cages had a greater adverse response to handling and transport. Other studies have shown that frequent visits and occasional handling by stockmen can reduce fearfulness of hens when they are handled during depopulation (Jones and Waddington, 1992; Scott and Moran, 1993).

There are indications that such procedures can reduce the potential damage during depopulation of caged hens (Reed *et al*., 1993). A group of birds which had contact with humans were observed during depopulation and given a potential damage risk score. A group which had no contact with humans had a significantly higher score. Actual damage was also rated as being higher for the birds with no previous human contact; however, the sample was too small to be statistically valid.

Conditioning procedures

Conditioning to modify behaviour is commonly practised and may be something that may be exploited to avoid fearfulness at depopulation. An example of a conditioning process is when farmyard hens run towards the sound of the bucket when fed. General discussions with researchers and catchers indicate that there may be value in:

- playing music or other sound that is representative of that during a depopulation, to help condition the birds;
- the catching crew wearing the same colour and type of clothing as those stockmen who are involved in non-fearful tasks such as feeding and egg collection, and that staff involved with tasks provoking fear, such as vaccinating, wear a different style and colour of clothing.

Eliminating Depopulation of Live Birds

Mills and Nicol (1990) showed that fearfulness was less in end-of-lay hens which had only been caught and removed from their cage than in those which had additionally been transported. They found considerable variations in response between individual birds. Duncan (1989) also crated birds and transported them for 40 min. Plasma cortisol concentrations of these birds were higher than for those birds which had only been caught and handled. Conversely, loading and unloading have been suggested as being more stressful (in terms of physiological responses) than the journey itself (Swarbrick, 1986). Whether it is transportation, catching or handling that is the more stressful event is uncertain, but insults applied simultaneously provide many more novel stimuli which could very well have additive effects, suggesting that eliminating the depopulation of live birds would bring benefits.

Provided it can be carried out effectively and efficiently, killing birds, either on-farm or in their cages, has the potential to improve the welfare of the end-of-lay hen at depopulation. However, the success of such practices has been mixed. For example, birds have been killed (due to an outbreak of salmonella) in the poultry house using modified atmosphere as a control measure (Anon., 1994a) but, in one case, problems with the spread of the gas caused birds to survive for over 2 days, causing serious welfare insults and suffering. There is an added potential complication in the EU because, unless the bird has been slaughtered by a method specified by the Meat Hygiene Regulations, the meat cannot be sold for human consumption. An improved system for using modified atmosphere is required if killing is to be done humanely, safely and economically. Such a system for a house would not be easy to devise, since the following criteria would need to be met:

- a fully sealable, probably purpose-built, poultry house;
- a quick-acting gas which, for safety, should leave no residue in the meat;
- quick and even dispersion of the gas to all hens;
- quick removal of the gas to allow humans to re-enter to remove hens;
- a non-human food chain market for the dead hens.

These factors, and the public perception of killing birds in this manner, will not allow a ready uptake of this approach in the UK.

Using the Hens' Living Accommodation as a Transport Container

Another approach would be to use the hens' living accommodation as a transport container. The technical difficulties could be overcome, but at some cost. Minimizing the volume for transport could be achieved by moving only part of the cage. An enriched cage with dust-bath and nesting-box compartments, and perhaps some form of manipulation, could be used to ensure that all the hens were contained in a suitable portion of the cage for this part to be removed and transported. The obvious difficulties are the high cost of such a system and the slow rate at which it would be installed and therefore taken up. There would still be a need to depopulate the cages at the processing plant.

Mechanized Handling

Berry *et al*. (1990) have shown that completely mechanized handling of broilers is possible and practical, with bird welfare comparable to the best manual handling. Duncan *et al*. (1986) showed that the short-term stress (assessed using heart rate recovery and tonic immobility) of birds harvested by machine was less than that of birds harvested by hand. Scott and Moran (1993) showed that the initial exposure to conveying is no less frightening for hens than being carried, inverted, by both legs. However, Duncan (1989) showed that manual catching and carrying over 6 m was more stressful than any other treatment, including conveying. Rutter *et al*. (1993) also showed that the noise of a conveyor can be as aversive as the movement, indicating that these systems must be evaluated for all the stimuli that the hens would receive. A study in Sweden by Ekstrand (1998) compared damage rates of mechanically caught and manually caught broilers. This study indicated that the mechanical system was acceptable for animal welfare when properly operated, although it did cause more damage than the careful manual catching system. In a later study by Knierim and Gocke (2003), injury rates were lower for the mechanical catcher than for manual catching, and the potential to limit impaired bird welfare during catching was noted.

The same harvesting principle in hen housing would only be practicable for some alternative housing systems where the hens are kept on deep litter or other open flooring. Adapting the harvesting head, possibly as a hand-held device, to extract hens from alternative housing systems could be done, but the resulting device would be cumbersome and impractical.

Over the years many other mechanized handling systems have been investigated, mainly for broilers, and these are described by Kettlewell and Turner (1985) and Scott (1993). However, not only are most of the ideas described intended for broilers, but it is noticeable that few of them have been developed. Scott (1993) reported that most systems use conveyors and these are a fundamental part of practically all mechanized systems.

Trials of the so-called Silsoe broiler harvester (Berry *et al.,* 1990) showed that broilers could be transported on conveyors without attempting to escape and that their heart rate, although raised, dropped to normal levels more rapidly than that of broilers carried manually (Duncan *et al.,* 1986), indicating that the birds were less stressed.

Moran *et al*. (1993) studied the development of multi-section conveyors for stocking and depopulating hens in battery cage housing systems. The conveyor system consisted of sections which allowed the hens to be transferred out of the shed at depopulation and into the shed for stocking. When assessed using behavioural responses such as escape attempts and wing flapping, the birds seemed to be little disturbed. The steady stream of birds encouraged individual handling of the hens, with a hand being placed either side of the body, so restraining the wings and preventing them from being caught in the cage opening. This system completely eliminated the need to invert the hen.

Although the conveyor system reduced damage and stress levels it was not taken up by the industry due to:

- the initial cost of the system (including an extra lorry to transport the conveyors);
- lack of room to lay out the conveyors in many commercial houses;

- the long setting up and packing up times (when the catchers could be removing hens);
- the potential compromise to biosecurity.

An alternative approach is to build a conveyor belt into the cage system. This idea has been used in the former Soviet states and elsewhere for broilers (Anon., 1980, 1994b; Shane and Rahn, 1980). These systems either have removable floors, allowing the birds to step down on to the manure belt, or a perforated belt floor which allows the droppings to fall through. The belt then moves the birds to the end of the shed where they can be placed directly into the transport containers. This type of system would require a very high capital investment, as all the cages would need to be replaced. Handling of the hens is still needed from the belt to the transport container.

It must be appreciated that the mechanical harvesting of broilers has not been adopted widely in the UK, although it is becoming widespread in the Danish, German and US industries. Given that broilers are usually in simpler housing, and are more placid and amenable to mechanized handling than hens are, then the lack of take-up of mechanical methods in the UK broiler industry indicates that a strong case would have to be made if the, arguably more problematical, layer hen depopulation procedures are to be mechanized.

Minimal Manual Handling

To improve the welfare of hens during stocking and depopulation, it has been suggested that manual handling should kept to a minimum and that the hens should be handled individually, without being inverted (Broom, 1990). Handling has been shown to compromise the physical (Gregory and Wilkins, 1989), physiological (Duncan, 1989) and behavioural (Duncan *et al*. 1986; Duncan, 1989; Mills and Nicol, 1990) well-being of the birds. Consequently, minimal catching and handling procedures should benefit bird welfare.

The Whurr module (Anon., 1995b) was developed for loading and transporting pullets with reduced handling. The aim of the system was to give a maximum of two handlings between catching at the rearing site and placing in the cages. This compared with up to six handlings with a more conventional system. The system used a module with 16 60 × 120 cm drawers. At the rearing farm, the pullets were lifted from the floor by their legs, carried inverted to the module, and placed directly into the drawers. The modules were then lifted from the floor by fork-lift truck and placed on to a lorry. At the farm, the module was lifted off the lorry and the drawers of pullets were removed and carried into the poultry house, where a stack of drawers was taken along an aisle on a small, specially designed lift truck. The pullets were then lifted from the drawers straight into the cage. With alternative housing systems, the pullets could be tipped gently from the drawers on to the floor without handling the individual birds.

Optimizing Working Conditions for the Catchers

Depopulating hens is arduous, unpleasant work carried out at unsociable times. There will be a relatively high turnover among the catching staff and many will not

be highly motivated. It is obvious, therefore, that the working conditions should be as satisfactory as possible in order to minimize stress, discomfort and inconvenience to the catching crew. S. Edge (Lincoln, personal communication) suggests that the following are some of the important points to consider for the catching staff before and during depopulation.

- Plan the task well, with adequate staff and time to complete the depopulation, especially if it is a difficult site, without rushing.
- Suitable access for the lorry to the site and also to every shed door so that the shortest carrying distances can be used.
- Secure, safe and well-lit access in the sheds as well as between the lorry and sheds.
- Suitably prepared sheds, including previous treatment for red mite, equipment for feeding and egg collection removed, controllable lighting, dust removed before depopulation and the ventilation system running during depopulation.
- Well-managed catching operation including agreed responsibility for overseeing the complete operation, availability of senior farm staff, appropriate supervision of catching staff and good channels of communication between haulier/catchers/farm and processing plant, including emergency telephone numbers.
- Good washing facilities available for the catching crew to use at all times.

Points such as these should be considered at each depopulation, as this will help to avoid stressing the catching crew and will encourage them to be careful with the hens during depopulation.

PROSPECTS FOR AN IMPROVED PRACTICAL DEPOPULATION SYSTEM

Jones (1996) reviewed and discussed fear in poultry and suggested ways of reducing fearfulness. Approaches suggested included: 'environmental enrichment, regular handling or related treatments, vitamin C supplementation of the diet or drinking water, and genetic selection'. While these treatments will not eliminate fear, their use might improve the welfare of hens being caught and handled during depopulation. As mentioned earlier, this could extend to include specific conditioning, targeted at the noise, movement and type of activity involved in a depopulation.

Although modifying behaviour to aid depopulation has been discussed, this needs to be considered in the context of the need for depopulation to be completed within a realistic time-frame.

Establishing control of the hens within the housing, whether cage or alternative system, is crucial. The housing conditions are often cramped, dusty and, if any alternative method is to be applied in the short-term, any modifications to existing housing will need to be minimized. The method should be quiet and flexible. As a means of controlling hens, it is difficult to see how well-trained catchers could be surpassed, especially if the procedure requires the catchers to catch individual hens and hold them by their sides.

The second task is to *transfer the hens to a transport mechanism*. If the hens were already under manual control, there is no reason why the transfer should not also be manual, particularly if the distance is minimal and the hens can remain upright.

Transporting the hens out of the building is the next stage. Potentially, conveyors present a means of removing birds from the building; however, they are not quick or easy to set up and, furthermore, there is a second controlling and handling operation needed at the downstream end of the conveyor. The belt will also have to be enclosed to prevent hens from escaping, making it difficult to monitor the hens' progress and creating a potential problem of hens becoming trapped. Vacuum, or pneumatic, conveying systems could be used; although suffering from the same problems as the belt conveyors, the problems could be potentially more acute, since it would be very difficult to free a hen trapped within the tubing.

For a general solution, the hens should be placed by hand, one at a time and without inverting, directly into a container which, once transported out of the house, will form part of the lorry load so that subsequent direct control and handling of the hens is eliminated completely. The requirements for this to work satisfactorily are:

- the ability to move large batches of hens within the building;
- a basic unit of suitable size to fit into existing loose-crate handling systems;
- a large opening into which the hens can be placed without inverting or forcing them;
- containers placed close to the catcher to ensure that birds can be lifted by their sides;
- a minimum amount of time spent holding the birds.

Subsequent control and transfer of the hens should be in batches of crates, or within modules, and selected existing materials handling equipment, such as pallet trucks and fork-lifts, should be used.

The advantages of this type of system are:

- minimized contact with humans;
- minimum number of handlings;
- inversion eliminated;
- individual handling of birds;
- reduced risk of damage to hens due to physical contact with shed furniture.

The main disadvantage is the capital cost of the equipment, but with care the system should be able to use low-cost, standard materials-handling components, and by moving birds in larger numbers it is likely that there would be a reduction in labour requirements.

A prototype system, developed from the Whurr system and using a wheeled module containing four drawers, which offer good access and hold around 60 hens, was built following these guidelines and trialled (Kristensen *et al.,* 2001). The trial showed a small reduction in overall injury, as assessed on the whole birds by a Meat Hygiene Inspector, from 3.52% to 2.66%. The time that a bird spent being handled was reduced greatly from over 65.4 to 4.5 s and the depopulation time for a batch of 450 hens was almost halved (15.3 min compared to 27.7 min for the conventional system). The catchers also showed a clear preference for the new modules.

The module is mounted on large castor wheels and it enables 60 hens to be moved easily by one person. The drawer size is similar to that of a loose crate and should be capable of entering the majority of cage and alternative housing systems so long as access doors are of a suitable size and any steps can be fitted with

ramps. In addition, the modules have been designed to give good ventilation when on the lorry.

CONCLUSIONS

When designing new cage systems, manufacturers should consider, in the context of bird welfare and the health and safety of the catcher, the ease with which birds can be depopulated from the housing system. Traditional cage systems are far from ideal for good hen welfare and are being modified. The new improved, enriched, cages should be assessed for difficulty of stocking and depopulation during their development.

Systems that allow hens relative freedom of movement in the house may make depopulation difficult for the catchers, as hens can escape and may have to be chased, causing damage to the hens and injury to the catchers. Again, this aspect should be considered by cage manufacturers.

It may be beneficial to investigate whether habituation, and particularly conditioning procedures, can be exploited to reduce the fear responses of hens to the depopulating processes.

Mechanical depopulation systems investigated and developed for broiler harvesting would be too cumbersome and are not feasible for use with hens in cages and most alternative housing systems.

The killing of birds using modified atmospheres in the housing systems would need purpose-built housing and uniform gas dispersion to ensure a quick, humane death, and even then would not be readily accepted by the public.

The planning and arranging of the depopulation should consider aspects that will minimize the chance of the catchers becoming stressed and so being less careful during depopulation.

Belt conveyor systems for transporting end-of-lay hens reduce skeletal damage but the long setting up time and relatively high cost discourage such a system from being accepted commercially. The birds also have to be handled twice; on to and off the conveyor.

Unless legislation is introduced, any system used for the depopulation of hens has to be:

- easy to operate;
- easy to set up;
- low in capital and operating costs due to the very low value of end-of-lay hens.

With these constraints it is likely that the best method would be to:

- manually catch individual hens;
- place them straight into a transport drawer or crate;
- use mechanical handling systems such as pallet trucks and rollers to move them to the lorry.

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REFERENCES

Anon. (1980) Cage system gets field trials here. *Broiler Industry* December 1980, 32–34.

Anon. (1994a) Layer tragedy rocks German market. *Poultry World* October 1994, 1–3.

Anon (1994b) Cages for broilers. *Poultry International* 31, 50–52.

Anon. (1995a) Spent hen processing. *Poultry International* 34, 72–74.

Anon. (1995b) Step into the future with the adaptable Whurr module. *Trade brochure*, Trevor Stearn Trucking, Norfolk.

Berry, P.S., Kettlewell, P.J. and Moran, P. (1990) The AFRC mark 1 experimental broiler harvester. *Journal of Agricultural Engineering Research* 47, 153–163.

Bolles, R.C. (1970) Species-specific defence reactions and avoidance learning. *Psychological Review* 77, 32–48.

Broom, D.M. (1986) Indicators of poor welfare. *British Veterinary Journal* 42, 524–526.

Broom, D.M. (1990) Effects of handling and transport on laying hens. *World's Poultry Science Journal* 46, 48–50.

DEFRA (2002a) *The Welfare of Farmed Animals (England) (Amendment) Regulations 2002*. Department of Environment, Food and Rural Affairs, The Stationery Office, London.

DEFRA (2002b) *Code of Recommendations for the Welfare of Livestock: Laying Hens*. Department of Environment, Food and Rural Affairs, London.

DEFRA (2003) *Egg Statistics Notice*. Department of Environment, Food and Rural Affairs. http://statistics.defra.gov.uk/esg/statnot/eggnotce.pdf (last accessed 15 April 2003).

Duncan, I.J.H. (1989) The assessment of welfare during the handling and transport of broilers. In: Faure, J.M. and Mills, A.D. (eds) *Proceedings of the 3rd European Symposium on Poultry Welfare*. Worlds Poultry Science Association, Beekbergen, The Netherlands, pp. 93–107.

Duncan, I.J.H. (1990) Reactions of poultry to human beings. In: Zayan, R. and Dantzer, R. (eds) *Social Stress*. Martinus Nijhoff, Dordrecht, The Netherlands, pp. 121–131.

Duncan, I.J.H., Slee, G.S., Kettlewell, P.J., Berry, P.S. and Carlisle, A.J. (1986) Comparison of the stressfulness of harvesting broiler chickens by machine and by hand. *British Poultry Science* 27, 109–114.

Ekstrand, C. (1998) An observational cohort study of the effects of catching method on carcase rejection rates in broilers. *Animal Welfare* 7, 87–96.

Fleming, R.H., Whitehead, C.C., Alvey, D., Gregory, N.G. and Wilkins, L.J. (1994) Bone structure and strength in laying hens housed in different husbandry systems. In: *Proceedings of the 9th European Poultry Conference, Glasgow, 7–12 August,* Vol. 1, pp. 284–285.

Freeman, B.M. (1984) Transportation of poultry. *World's Poultry Science Journal* 40, 19–30.

Gregory, N.G. and Wilkins, L.J. (1989) Broken bones in domestic fowl: handling and processing damage in end-of-lay battery hens. *British Poultry Science* 30, 555–562.

Gregory, N.G. and Wilkins, L.J. (1992) Skeletal damage and bone defects during catching and processing. In: Whitehead, C.C. (ed.) *Bone Biology and Skeletal Disorders in Poultry*. Carfax, Abingdon, UK, pp. 313–328.

Gregory, N.G., Wilkins, L.J., Kestin, S.C., Belyavin, C.G. and Alvey, D.M. (1992)

Effect of husbandry system on broken bones and bone strength in hens. *Veterinary Record* 128, 397–399.

Gregory, N.G., Wilkins, L.J., Knowles, T.G., Sorensen, P. and Van Niekerk, T. (1994) Incidence of bone fractures in European layers. In: *Proceedings of the 9th European Poultry Conference, Glasgow, 7–12 August, Vol. 2*, pp. 126–128.

Hansen, I., Braastad, B.O., Storbraten, J. and Tofastrud, M. (1993) Differences in fearfulness indicated by tonic immobility between laying hens in aviaries and in cages. *Animal Welfare* 2, 105–112.

Jones, R.B. (1982) Effects of early environmental enrichment upon open field behaviour and timidity in the domestic chick. *Developmental Psychobiology* 15, 105–111.

Jones, R.B. (1985) Fearfulness of hens caged individually or in groups in different tiers of a battery and the effects of translocation between tiers. *British Poultry Science* 26, 399–408.

Jones, R.B. (1996) Fear and adaptability in poultry: insights, implications and imperatives. *World's Poultry Science Journal* 52, 131–174.

Jones, R.B. and Waddington, D. (1992) Modification of fear in domestic chicks *Gallus domesticus* via regular handling and early environmental enrichment. *Animal Behaviour* 43, 1021–1034.

Jones, R.B., Duncan, I.J.H. and Hughes, B.O. (1981) The assessment of fear in domestic fowl exposed to a looming human stimulus. *Behavioural Processes* 6, 917–924.

Kannan, G. and Mench, J.A. (1996) Influence of different handling methods and crating periods on plasma corticosterone concentrations in broilers. *British Poultry Science* 37, 21–23.

Kannan, G. and Mench, J.A. (1997) Prior handling does not significantly reduce the stress response to pre-slaughter handing in broiler chickens. *Applied Animal Behaviour Science* 51, 87–99.

Kettlewell, P.J. and Turner, M.J.B. (1985) A review of broiler chicken catching and transport systems. *Journal of Agricultural Engineering Research* 31, 93–114.

Knierim, U. and Gocke, A. (2003) Effect of catching broilers by hand or machine on rates of injuries and dead-on-arrivals. *Animal Welfare* 12, 63–73.

Knowles, T.G. and Broom, D.M. (1990) The handling and transport of broilers and spent hens. *Applied Animal Behaviour Science* 28, 75–91.

Kristensen, H., Berry, P.S. and Tinker, D.B. (2001) Depopulation systems for spent hens: a preliminary evaluation in the UK. *Journal of Applied Poultry Research* 10, 172–177.

Mills, D.S. and Nicol, C.J. (1990) Tonic immobility in spent hens after catching and transport. *Veterinary Record* 126, 210–212.

Moran, P., Whetlor, W.C. and Berry, P.S. (1993) A conveyor system for handling layers. *Agricultural Engineer* 48, 120–122.

NFU (2003) *Egg Production Quarterly* May 2003. National Farmers Union, Newmarket, Suffolk.

Prescott, N.A., Berry, P.S., Haslam, S. and Tinker, D.B. (2000) Catching and crating turkeys: effects on carcass damage, heart rate and other welfare parameters. *Journal of Applied Poultry Research* 9, 424–432.

Reed, H.J., Wilkins, L.J., Austin, S.D. and Gregory, N.G. (1993) The effect of environmental enrichment during rearing on fear reactions and depopulation trauma in adult caged hens. *Applied Animal Behaviour Science* 36, 39–46.

Rutter, S.M., Scott, G.B. and Moran, P. (1993) Aversiveness of mechanical conveying to laying hens. *Applied Animal Behaviour Science* 36, 337–345.

Savory, C.J., Seawright, E. and Watson, A. (1992) Stereotyped behaviour in broiler breeders in relation to husbandry and opioid receptor blockage. *Applied Animal Behaviour Science* 32, 349–360.

Scott, G.B. (1993) Poultry handling: a review of mechanical devices and their effect on bird welfare. *World's Poultry Science Journal* 49, 44–57.

Scott, G.B. and Moran, P. (1993) Fear levels in laying hens carried by hand and by mechanical conveyors. *Applied Animal Behaviour Science* 36, 337–345.

Shane, M.S. and Rahn, A.P. (1980) Cages for broilers: time favours change. *Broiler Industry* September, 20–26.

Swarbrick, O. (1986) The welfare during transport of broilers, old hens and replacement pullets. In: Grandin, T.E. (ed.) *The Welfare of Animals in Transit*. British Veterinary Association Animal Welfare Foundation, London, pp. 82–97.

Thompson, F. and Spencer, W.A. (1966) Habituation: a model phenomenon for the study of neuronal substrates of behaviour. *Psychology Review* 73, 16–43.

Wechsler, B. (1995) Coping and coping strategies: a behavioural view. *Applied Animal Behaviour Science* 43, 123–134.

Whitehead, C.C. and Fleming, R.H. (2000) Osteoporosis in cage layers. *Poultry Science* 79, 1033–1041.

CHAPTER 30
Transport of chicks, pullets and spent hens

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ABSTRACT

Despite regional economic pressures, worldwide poultry production continues to expand. In the year 2002 the number of layer chick placements in the European Union (EU-15) was 290 million. The corresponding production figure for the UK was 32.5 million layer chicks. Laying birds experience more episodes of transport than other types of chicken (e.g. broilers) as they are first transferred from the hatchery to a growing site but are subsequently relocated as pullets to the production farms. At the end of lay, the birds are finally transported to the slaughter house or processing unit.

Transport of livestock is regarded as a major source of stress and reduced welfare, and a major cause of these problems is the thermal micro-environment in transit. It is essential to ensure that 1-day-old chicks are transported in conditions imposing minimal thermal stress in well-ventilated containers. The thermal environment should be homogeneous (well-mixed) within the vehicle transport space. Transport conditions for 1-day-old chicks have been reported to influence the subsequent incidence of a range of pathologies. Many other factors may also contribute to transport stress, such as handling, feed and water withdrawal, vibration, space restrictions upon behaviour, noise, pollutants and vaccination.

Pullets may be transported in a range of containers and vehicle types. Some are purpose-built modules which may be wheeled into the house for direct unloading into cages. Such systems may employ dedicated vehicles. Other transport container types are often used, including fixed crates. Pullets have a relatively high commercial value and are carefully handled. These birds also have good feather cover and, when healthy, can withstand a wide range of thermal conditions. Recent research has demonstrated some aversion of young hens to vibration and certain thermal conditions that may be encountered in transit.

The transport of spent hens to processing plants for slaughter constitutes a particular cause for concern in relation to hen welfare. The hens have relatively little economic value and thus there is little financial incentive to encourage careful handling and good welfare in transit. In addition, the number of processing plants able or willing to handle spent layers is much fewer than those dealing with broilers and, as a consequence, journeys between farm and slaughter may be of much longer duration than for meat-type birds. In addition, the pre-transport handling of layers (depopulation) may result in excessive skeletal trauma, mainly due to the fragility of the bones resulting from the altered calcium economy associated with prolonged egg (shell) production. Pre-

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transport injury, fractures and dislocations will result in painful conditions and the effects will be exacerbated by transportation. It should be noted that hens with unhealed old bone breaks, or fresh breaks, could not be legally transported under current EU legislation because transportation would inevitably lead to greater potential pain and suffering, therefore making the birds 'unfit for transport'. In addition, poor feathering and depressed metabolism due to prolonged feed withdrawal and transport times may make spent hens excessively vulnerable to the effects of cold and or wet conditions, particularly at high air speeds. Paradoxically, the over-enthusiastic 'protection' of loads of spent layers by means of tarpaulins on the trailers, particularly when vehicles are stationary for prolonged periods and during warm weather, may result in mortalities and reduced welfare.

This chapter examines the transport of chicks, pullets and spent hens.

INTRODUCTION

Despite regional economic pressures, worldwide poultry production continues to expand. In the year 2002 the world population of laying hens was 5.3 billion. The number of layer chick placements in the 25 States was 488 million, whilst in the present European Union (EU-15) it was 290 million (FAOSTAT, 2003). The corresponding production figure for the UK is 35 million layer chicks. Laying hens experience more episodes of transport than other types of chicken (e.g. broilers), as they are first transferred from the hatchery to a growing site, but are subsequently relocated as pullets to the production farms. At the end of lay, the hens are finally transported to the slaughter house or processing plant. Thus it may be calculated that in any one year chickens reared for egg production will experience in excess of 15 billion bird journeys of varying duration and under a wide range of climatic conditions and in containers and vehicles of widely differing designs and operational specifications. Despite the obvious numerical and economic importance of the transport and procedures involving laying hens, pullets and chicks, there has been relatively little research focused specifically upon the transport of laying hens. There is, however, a considerable literature relating to the transport of broiler chickens (and other livestock), and many of the methodologies, findings and principles derived from such studies are applicable to laying strains. Clearly the spectrum of concurrent stressors imposed in routine hen and chick transportation must pose a threat to bird welfare, and it is essential to employ the available research information as the basis for improved transport procedures, vehicle design and operation and codes of practice and regulations. One-day-old chick transport has been reviewed recently (Mitchell *et al*., 2002). The transport of laying hens has been discussed previously by Knowles and Broom (1990a,b), Knowles (1994) and Weeks and Nicol (2000), although little detail on the influence of the vehicle micro-environment is described. It is considered appropriate to review the general areas of transportation of chicks and more mature poultry and to consider the welfare implications and to highlight those aspects most pertinent to the transportation of laying hens.

TRANSPORT OF 1-DAY-OLD CHICKS

Thermal stress may be the major source of welfare compromise during the transportation of day-old chicks. Whilst commercial breeders and producers have long recognized the necessity to maintain an appropriate thermal environment for chicks in transit (Tamlyn and Starr, 1987; Freij, 1988; Laughlin, 1989; van der Hel and Henken, 1990; Qureshi, 1991; van der Hel *et al*., 1991) the conditions employed have been largely defined by empirical means and have been based upon minimization of mortality rates during and following transport, and efficient productivity during the subsequent rapid growth phase. In current practice the recommended temperature for chick transport is 24–26°C (Ross Breeders, 1996; Meijerhof, 1997; Weeks and Nicol, 2000), although only the Ross Breeders technical publication (1996) includes a recommendation for controlled humidity (75% at 24°C). It is suggested, therefore, that to simultaneously optimize survival, productivity and welfare of the newly hatched chick in transit, an effective strategy would be to match the thermal characteristics of the micro-environment to the biological requirements of the birds. Some previous studies have attempted to define thermoneutral or optimal environments for neonatal chicks on the basis of metabolic heat production and body temperature responses (Misson, 1976; Gates *et al*., 1989; Henken *et al*., 1989; van der Hel *et al*., 1991). Generally these studies did not measure other indicators of homeostatic effort which might better define the physiological impact of the thermal micro-environment. More recently, Xin and Harmon (1996) examined the effects of a range of temperatures and humidities (20–35°C and 40–17%) upon day-old chicks by measuring metabolic rate and mortality. They concluded that optimum or thermoneutral conditions occurred between 30–32°C. Xin (1997) has also reported that chicks held at a constant 29°C do not exhibit a different mortality or body weight loss compared to birds exposed to as much as a 16°C cycling temperature around the same mean temperature. Mitchell *et al*. (1996) employed physiological stress modelling, measurement of metabolic rate and the concept of apparent equivalent temperature or AET (Mitchell and Kettlewell, 1998; Mitchell *et al*., 2001a,b) to determine optimum transport thermal environments for 1-day-old chicks. Apparent equivalent temperature takes account of the humidity of the air and is therefore a better index than temperature alone of the physiological stress to which the bird is subjected. All measurements were performed on chicks in commercial transport containers in calorimeter chambers housed in controlled-climate rooms. Temperatures of 20–35°C accompanied by relative humidities (RH) of 50–65% and durations of exposure of 3–12 h were employed. Metabolic heat production ranged from 7.8 ± 0.3 to 8.7 ± 0.9 W kg^{-1} in close agreement with previously published values (van der Hel *et al*., 1991; Tanaka and Xin, 1997a). On the basis of minimal change in body temperature and minimal alterations in basal metabolic rate, hydration state, electrolyte balance, body weight loss and plasma metabolite concentrations, an optimal temperature/humidity range of 24.5–25.0°C and 63–60% RH for the transport of chicks at commercial stocking density was identified. It was emphasized that these physiologically ideal conditions are very similar to those currently employed by commercial breeders and producers. The studies also provided evidence that if the thermal micro-environment is appropriately controlled, then journey durations of at least 12 h are wholly acceptable. It is concluded that both productivity and welfare of day-old chicks in transit can be maintained by careful

regulation of the temperature and water vapour density to these prescribed limits inside the transport containers.

The ultimate determinants of the localized on-board vehicle (chick transporter) micro-environment are the prevailing climatic conditions, the addition of heat and water vapour to the load space from all sources including the bio-load (chicks) and the ventilation rate and distribution. All these issues have been extensively addressed in relation to the transport of broiler chickens at slaughter age (e.g. Hoxey *et al.*, 1996; Kettlewell *et al.*, 2000), but the corresponding characteristics of chick transporters have received less detailed study. Up-to-date measurements of heat and moisture production of chicks are available for calculation of vehicle ventilation requirements (Tanaka and Xin, 1997b; M.A. Mitchell *et al.*, unpublished) but only the work of Quinn and Baker (1997) appears to have examined in detail the ventilation characteristics of commercial chick transporters. The important findings included the observation that the presence of the load of stacked chick boxes had a channelling effect upon the airflow through the load space, with significant amounts of air by-passing the chick boxes and being re-circulated. The implications of this ventilation regime for airflow in the chick containers was seen in the temperature distributions, with peak temperatures occurring in the front central boxes and cooler air by-passing the load. In addition, cooler air entered from beneath the vehicle in the fully loaded configuration and reduced flow through the load as well as potentially introducing exhaust fumes into the load space. All the principles of well-ventilated containers and vehicles and control and homogeneity of the thermal micro-environment must apply to the carriage of laying hen chicks. Their welfare and growth, development and performance may be markedly influenced by the first episode of transportation between hatchery and rearing site. It may be concluded that for 1-day-old chick transport that:

- Thermal conditions should be controlled more effectively to improve chick welfare.
- Air mixing is an important issue.
- More effective ventilation systems should be developed (including containers) to ensure thermal homogeneity of the 'on-board' micro-environment and to optimize welfare.

POULTRY TRANSPORT AND WELFARE

In transit, birds may be exposed to a variety of potential stressors including the thermal demands of the transport micro-environment, acceleration, vibration, motion, impacts, fasting, withdrawal of water, social disruption and noise (Nicol and Scott, 1990; Mitchell *et al.*, 1992; Mitchell and Kettlewell, 1993, 1998). Each of these factors and their various combinations may impose stress upon the birds in transit but it is well recognized that thermal challenges, and in particular heat stress, constitute the major threat to animal well-being and productivity (Mitchell and Kettlewell, 1998; Mitchell *et al.*, 2000; Weeks and Nicol, 2000; Nilipour, 2002). The imposition of thermal loads upon the birds in transit will thus result in moderate to severe thermal stress and consequent reduced welfare (Mitchell *et al.*, 1992; Mitchell and Kettlewell, 1998), increased mortality due to either heat or cold stress (Hunter *et al.*, 2001), and induced pathology including muscle damage and associated changes in product quality (Gregory, 1998; Mitchell, 1999).

The adverse effects of 'transportation stress' may range from mild discomfort and aversion to pathology and death. The stressful nature of transportation is well recognized in all species (Hails, 1978; Cockram and Mitchell, 1999; Knowles and Warriss, 2000) including poultry (Mitchell and Kettlewell, 1998; Weeks and Nicol, 2000). The association of transport stress with reduced welfare may be evidenced by a wide range of frequently reported physiological, biochemical, behavioural and pathological responses, and these may lead to overt morbidity, injury and mortality in transit (Cockram and Mitchell, 1999). Immunological suppression and increased susceptibility to infection resulting from transport stress and activation of the hypothalamo-pituitary-adrenocortical axis may be important longer term effects of transport, which are superimposed upon the more acute influences upon metabolite distributions, hydration state and numerous physiological systems. Whilst all such studies are valuable in that they indicate the stressfulness of transportation, it may now be proposed that merely demonstrating the existence of stress is insufficient and future progress is dependent upon the establishment of quantitative relationships between individual stressors or their combinations and a range of physiological stress indices reflecting the full range of adaptive responses exhibited by the animals (Mitchell and Kettlewell, 1998; Mitchell *et al*., 2001a). In addition, such physiological response models must account for the adequacy of the homeostatic strategies, the degree of homeostatic success and the disturbances in each of the relevant controlled variables (Mitchell *et al*., 2001a). Previous studies have failed to prioritize the effects of individual stressors and to determine the acceptable thresholds or limits for exposure. Physiological modelling applied to animal transportation requires a foundation of accurate and well-controlled simulation studies relating to the major stressors imposed in transit and such transport simulations have been successfully employed in poultry, pigs and calves. Whilst it is acknowledged that the transport microclimate may play a central role in the induction of transport stress, in particular temperature and humidity and their interdependence upon ventilation (Cockram and Mitchell, 1999), few studies have attempted to quantitatively relate physiological stress responses to quantified stressors, e.g. thermal challenges of defined magnitude and duration. It is thus essential to fully characterize the physiological responses, especially thermoregulatory effort and adequacy, of livestock under transport conditions and to relate these to other indices of stress during exposure to precisely defined thermal loads. Only through such comprehensive physiological modelling can the degree of stress imposed by the various components of the transport process be assessed holistically and related to the animals' welfare and the findings be usefully employed in the definition of optimum environments and the development of practical strategies for reducing transport stress to acceptable levels. Physiological response modelling of this type, in parallel with a knowledge of the physical and engineering principles underlying animal transport vehicle ventilation, has been utilized as the basis for the successful development of fan-ventilated commercial broiler transport vehicles in the UK (Kettlewell and Mitchell, 2001a,b; Kettlewell *et al*., 2001a,b).

In studies on the transportation of broiler chickens, models incorporating the use of apparent equivalent temperature (AET) have been employed to define the 'thermal comfort zones' for birds under commercial conditions. Clearly thermal environments which cause deep body temperature to approach the upper or lower lethal limits will increase mortality and must be regarded as totally unacceptable. Other thermal loads, however, will result in the bird exhibiting a range of

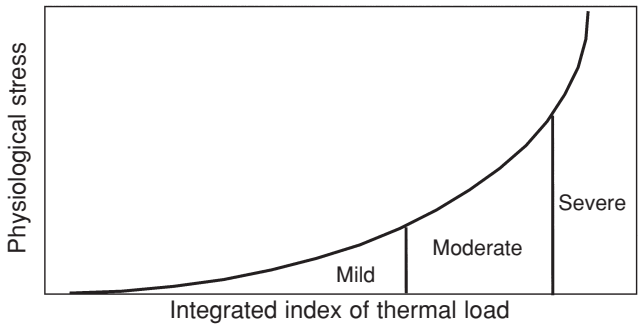

Fig. 30.1. Physiological stress response versus integrated thermal load.

thermoregulatory responses aimed at minimization of the change in deep body temperature. The adequacy of these responses may be judged by measurement of deep body temperature and the thermoregulatory effort involved can be assessed from physiological monitoring, e.g. panting rate in the heat and shivering rate in the cold, changes in metabolic rate and disturbances in blood gases and acid–base status. The physiological stress response model may thus be based upon the relationships between these responses and a single integrated index of the thermal load imposed upon the birds. The hypothetical relationship between a given physiological variable, thermal load and the severity of stress is shown in Fig. 30.1.

In these studies, birds were held in commercial transport crates and placed in controlled climate chambers for a period of 3 h (typical of commercial journeys). Various combinations of temperature/humidity were employed in the range 10–35°C and 30–95% RH. Thermoregulatory success (deep body temperature) and thermoregulatory effort (blood pH and gas disturbances) were correlated with the actual imposed thermal load (temperature/humidity combination).

'Apparent equivalent temperature' (AET) was used as an index of thermal load. This parameter is derived from the temperature, water vapour pressure and the psychrometric constant and describes the total heat exchange between a wetted surface and the environment.

$$\theta^*_{\text{app}}. = T + (e/\gamma^*)$$

where θ^*_{app} = AET, T = absolute temperature (K), e = water vapour pressure (mbar) and γ^* = corrected psychrometric constant (mbar K^{-1})

$$\gamma^* = \gamma\,(r_v/r_h)$$

where r_v = the resistance to water vapour transfer (sm^{-1}) and r_h = the resistance to heat transfer (sm^{-1}).

Using the AET approach, the combinations of temperatures and humidities which produce equivalent biological effects were determined. The relationship between change in deep body temperature and AET is presented in Fig. 30.2. It is clear that the response to thermal load is similar to the hypothetical curve presented in Fig. 30.1 and as such allows definition of temperature/humidity combinations imposing mild, moderate and severe physiological stress. Similar response patterns were observed for changes in blood pH and pCO_2.

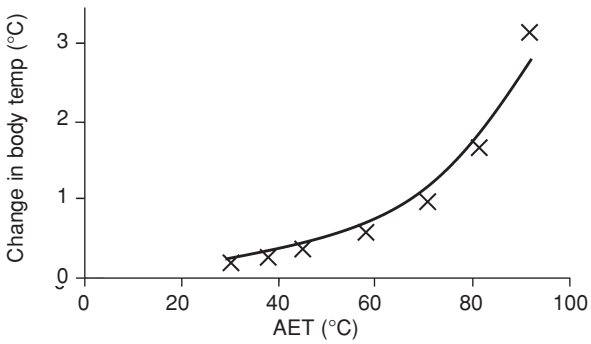

Fig. 30.2. Relationship between change in deep body temperature and apparent equivalent temperature (AET).

In a parallel series of experiments the effects of low environmental temperatures accompanied by wetting and air movement were examined. The experimental protocol was as for heat stress but the temperature range employed was –4°C to +12°C with a constant air speed (supplied from a laminar flow cabinet) of 0.7 m/s. For each temperature employed, birds were either exposed to dry conditions or were intermittently wetted by spraying for 1 min every 30 min. The experimental conditions were based upon characterization of the environments on typical commercial broiler transporters in the UK. Measurements of deep body temperature were made before and after exposure to each temperature/airspeed/wetting combination. In addition some birds were surgically implanted with deep body temperature data loggers to allow continuous recording of this variable. The degree of physiological stress imposed was assessed by the extent of the reduction in body temperature in each set of conditions.

In the cold stress studies surface wetting (at constant air speed of 0.7 m/s) had a profound effect upon thermoregulatory success with an increasing degree of hypothermia across the whole range of chamber temperatures employed. At 12°C the fall in rectal temperature in wetted birds was 3.03 ± 1.75°C, an additional decrease of 2.1°C compared with the corresponding 'dry' group. In wetted birds, the relationship between the change in rectal temperature (T_r) and T_e could be described by $y = 2.9E + 66x^{-26.9}$. Marked hypothermia was therefore induced at all other chamber temperatures and ranged from a reduction of 4.4 ± 3.2°C at T_e = 8°C to a maximum and life threatening fall of 14.2 ± 5.4°C when T_e = –4°C. As lethal deep body temperature in the fowl is 24°C, then from the derived relationship between environmental temperature and the change in core temperature (Fig. 30.3) it is apparent that a lethal hypothermia will occur in all wetted birds when T_e = –9.5°C and marked elevations of mortalities will be observed if T_e falls to only +1.0°C. These findings from this model define the lower limits for temperature exposure in transported broilers in wet conditions (Hunter *et al.*, 1997; Mitchell *et al.*, 1997, 2000, 2001b).

Physiological stress response modelling, exploiting the concept of apparent equivalent temperature (AET), has thus allowed identification of 'safe', 'alert' and 'danger' combinations of temperature and humidity which equate to mild, moderate and severe physiological stress. The model thus permits the definition of

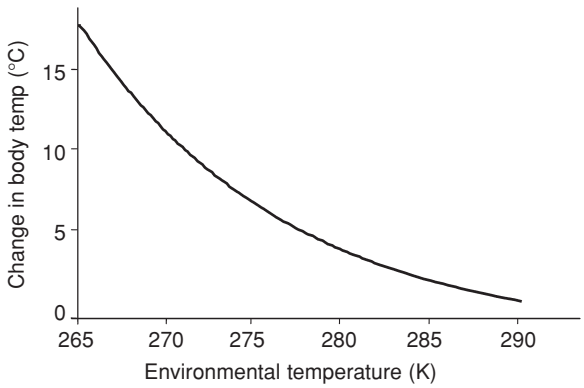

Fig. 30.3. Relationship between change in deep body temperature in wetted birds and environmental temperature (K).

thermal comfort zones for broilers in transit as presented in Fig. 30.4. At temperature/humidity combinations yielding AET values of 40–45°C or less, thermal stress will be minimal in transit. At temperature/humidity combinations giving AETs around 40–45°C, moderate thermal stress will occur, with some degree of hyperthermia and acid–base disturbances. At AETs of 65°C or greater, physiological stress may be deemed severe and mortalities will increase. Such thermal loads must be considered unacceptable.

This novel experimental approach has provided data specific to transportation conditions and which are directly applicable to commercial practice. Using physiological response modelling, the optimum thermal envelope for broiler carriage has been defined in terms of the 'physiological thermal comfort zones' and factors precipitating or contributing to the incidence of thermal stress have been identified.

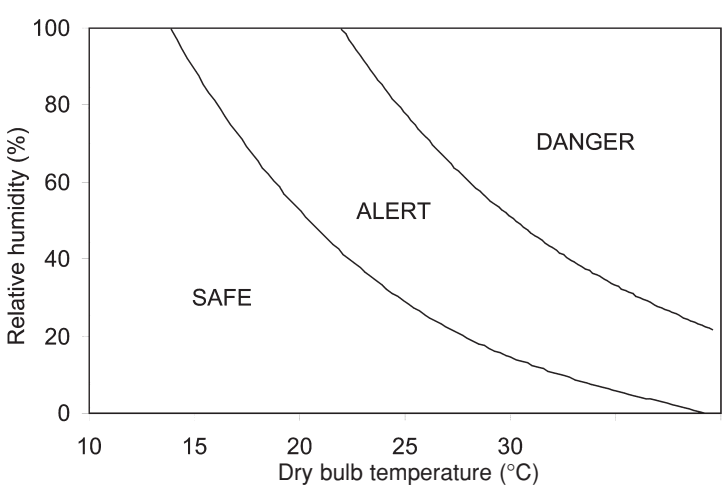

Fig. 30.4. 'Thermal comfort zones' for broiler transport (safe limit AET = 40°C ; danger limit AET = 65°C or greater).

APPLICATIONS TO PULLETS AND SPENT LAYING HENS

Pullets at the point of transfer to the layer farm are generally well feathered and are fully fed and hydrated and free from metabolic disease. Their thermoregulatory capacity may be regarded as optimal and thus they may be able to withstand greater excursions in ambient thermal conditions than either day-old chicks or spent hens. The physiological response models derived for broilers are thus likely to be applicable and the recommendations for the acceptable thermal envelope will be as described for the meat birds (Mitchell and Kettlewell, 1998). It might be proposed that for these high-value birds, mechanical ventilation ensuring homogeneous distributions of temperature and humidity within the bio-load and improved control of the 'on-board' thermal micro-environment and higher standards of welfare in transit may prove cost-effective.

Spent laying hens present a number of major challenges concerning welfare during transportation. Spent layers are reported to exhibit increased fear following transportation as assessed by measurement of tonic immobility responses (Mills and Nicol, 1990). These birds did not appear to habituate to transport stress on journeys lasting up to 5 h. The well-recognized, high incidence of bone fractures in birds at the end of lay (Knowles and Broom, 1990a,b; Knowles and Wilkins, 1998) also constitutes a major cause for concern during transportation (Knowles and Broom, 1990a,b; Knowles *et al*., 1993; Knowles and Wilkins, 1998). It is clear that birds with new fractures associated with depopulation or old unhealed fractures are 'unfit for transportation' and as such should not be taken to the slaughter house. Any pain or suffering associated with such injuries will be exacerbated by the accelerations, vibrations and impacts imposed during the journey. It may be suggested that motion and vibration represent a significant stressor in the absence of any injury, as hens exhibit aversion to specific frequencies typical of those encountered on commercial transport vehicles (Rutter and Randall, 1993; Scott, 1994; Weeks and Nicol, 2000).

Laying hens are often very poorly feathered at the point of transfer to the slaughter house and may be subject to 'physiological fatigue'. These problems may be exacerbated by prolonged pre-transport feed withdrawal. These factors will compromise their ability to thermoregulate in the face of thermal challenges, particularly if ambient temperatures are low. The reduction in peripheral insulation will make the birds more vulnerable to forced convective cooling and to the detrimental effects of wetting on 'open vehicles' at low ambient temperatures. Webster *et al*. (1993) and Weeks *et al*. (1997), using physical models of chickens to estimate the heat exchange of poultry in transit, have reported that even for well-feathered birds the conditions necessary for thermal comfort are rarely achieved on passively ventilated vehicles. That work also confirmed the large difference in the 'thermal comfort zone' between well-feathered broilers or pullets (10–15°C) and poorly feathered spent layers (22–28°C) in passively ventilated open vehicles. A further implication of the findings was the heterogeneous distribution of ventilation within the bio-load and the risk of localized over-ventilation in such circumstances (mean air speed within the transport crate between 0.9–2.4 m/s and a maximum air speed of 6.0 m/s). From these findings and those relating to the thermal micro-environments on broiler transporters and the associated ventilation regimes, a number of recommendations concerning the carriage of spent layers may be presented for improved procedures, practices and vehicle operation.

- The thermal limits for spent layer transport should be around 12–28°C accompanied by relative humidities of no more than 75% at temperatures greater than 22°C.
- Wetting of birds should be avoided at all temperatures of 12°C or less.
- Localized high air velocities should be avoided on passively ventilated vehicles by close attention to curtain construction and air inlet control.
- Journey times should be minimal and before a journey is undertaken the weather conditions should be taken into account, e.g. even at a temperature of 12°C the welfare of wetted birds will be severely compromised on any journey of >3 h duration.
- Wherever possible, both ambient conditions (temperature and humidity) and 'on-board' conditions should be monitored and recorded.
- Vehicle thermal environments should be controlled wherever possible (mechanical ventilation).

SUMMARY

One-day-old chicks are transported mainly by road to the first destination. It is widely recognized that the husbandry of the birds during this period and the conditions under which they are maintained immediately prior to and after placement are vital in determining subsequent performance and health status. Transport constitutes a major source of stress and reduced welfare, and a major cause of these problems is the thermal micro-environment in transit. Transport conditions for 1-day-old chicks will influence subsequent incidence of a range of pathologies as well as affecting growth and development. It is essential to ensure that 1-day-old chicks are transported in conditions imposing minimal thermal stress in well-ventilated containers. The thermal environment should be homogeneous (well-mixed) within the vehicle transport space. Current evidence suggests that optimum conditions within the transport container should be 24–25°C accompanied by a relative humidity of 55–65%. Chicks would normally be transported under such conditions for a maximum of 12 h at a space allowance of 21–25 cm^2/chick. Many other factors may also contribute to transport stress, such as handling, feed and water withdrawal, vibration, space restrictions upon behaviour, noise, pollutants and vaccination.

Hens are reared as pullets, either in cages or on litter, reaching point of lay at about 18 weeks of age. They are then transported to the egg-producing farms where they are either housed in battery cages or in 'alternative' systems. Pullets may be transported in a range of containers and vehicle types. Some producers use purpose-built modules, which may be wheeled in to the house for direct unloading into cages. These systems may employ dedicated vehicles. Other transport container types are often used, including fixed crates. Pullets have a relatively high commercial value and are handled carefully. These birds also have good feather cover and when healthy can withstand a wide range of thermal conditions. Recent research has demonstrated some aversion of young hens to vibration and certain thermal conditions that might be encountered in transit. Other work has defined the thermal comfort zones for birds during transportation. Based on the available information, it may proposed that the upper and lower limits for container temperature for these birds during a journey should be 26 and 8°C,

respectively. This is assuming a space allowance of 180–200 cm^2/bird and journey duration no greater than 12 h.

The transport of spent hens to processing plants for slaughter constitutes a particular cause for concern in relation to bird welfare. The hens have relatively little economic value and thus there is little financial incentive to encourage careful handling and good welfare in transit. In addition, the number of processing plants able or willing to handle spent layers is much smaller than those dealing with broilers and, as a consequence, journeys between farm and slaughter may be of much longer duration than for meat-type birds. In addition, the pre-transport handling of layers (depopulation) may result in extensive skeletal trauma, mainly due to the fragility of the bones resulting from the altered calcium economy associated with prolonged egg (shell) production. Pre-transport injury, fractures and dislocations will result in painful conditions and the effects will be exacerbated by transportation. It should be noted that hens with unhealed old bone breaks, or fresh breaks, could not legally be transported under current EU legislation because transportation would inevitably lead to greater potential pain and suffering, therefore making the birds 'unfit for transport'. In addition poor feathering and depressed metabolism due to prolonged feed withdrawal and transport times may make spent layers excessively vulnerable to the effects of cold and or wet conditions, particularly at high air speeds. Paradoxically, the over-enthusiastic 'protection' of loads of spent layers by means of tarpaulins on the trailers, particularly when vehicles are stationary for prolonged periods and during warm weather, may result in mortalities and reduced welfare.

It is proposed from physiological response modelling that thermal environments for spent layers in transit should conform to those recommended for broiler birds. These acceptable ranges and limits for temperature and humidity can be applied assuming space allowances of 160 cm^2 or more per bird and journey times of less than 12 h. For spent layers, particular attention should be paid to the thermal conditions and cold and wetting should be avoided wherever possible. Journey durations should be kept to an absolute minimum and holding of the loads stationary should be avoided. The use of mechanically ventilated vehicles for transportation of spent layers is recommended despite the obvious financial implications. Alternatives to transport of hens to slaughter such as 'on-site' slaughter and disposal should be considered in order to improve the overall welfare of the production process. Transport of laying birds as chicks, pullets and spent hens all represent causes for welfare concern, with the major problems being associated with the hens at end of lay. The transport procedures, containers and vehicles employed for laying hens at every stage of development and production can all be improved to increase welfare standards.

REFERENCES

Cockram, M.S. and Mitchell, M.A. (1999) Role of research in the formulation of rules to protect the welfare of farm animals during road transportation. In: Russel, A.J.F., Morgan, C.A., Savory, C.J., Appleby, M.C. and Lawrence, T.L.J. (eds) *Farm Animal Welfare: Who Writes the Rules? Occasional Publication* No 23. British Society of Animal Science, Edinburgh, pp. 43–64.

FAOSTAT (2002) http://apps.fao.org.

Freij, M. (1988) Chicks need cool transport. *Poultry International (Misset)* 4 (3), 18–19.

Gates, R.S., Turner, L.W., Turner, G.M. and Tuttle, J.W. (1989) Measured heat production in chicks. *Proceedings of the ASAE,* paper no. 894513.

Gregory, N.G. (1998) Livestock presentation and welfare before slaughter. In: Gregory, N.G. and Grandin, T. (eds) *Animal Welfare and Meat Science*. CAB International, Wallingford, UK, pp. 15–41.

Hails, M.R. (1978) Transport stress in animals: a review. *Animal Regulation Studies* 1, 289–343.

Henken, A.M., van der Hel, W., Hanssen, E.J.M., Scheele, C.W. and van Kampen, M. (1989) The effect of dry and wet bulb temperature on heat production of newly hatched chicks. In: Verstegen, M.W.A. and Henken, A.M. (eds) *Energy Metabolism in Farm Animals*. Martinus Nijhoff, Dordrecht, The Netherlands, pp. 291–294.

Hoxey, R.P., Kettlewell, P.J., Meehan, A.M., Baker, C.J. and Yang, X. (1996) An investigation of the aerodynamic and ventilation characteristics of poultry transport vehicles. 1. Full scale measurements. *Journal of Agricultural Engineering Research* 65, 97–113.

Hunter, R.R., Mitchell, M.A. and Matheu, C. (1997) Distribution of 'dead on arrivals' within the bio-load on commercial broiler transporters: correlation with climate conditions and ventilation regimen. *British Poultry Science* 38 (Suppl.), S7–S9.

Hunter, R.R., Mitchell, M.A. and Matheu, C. (2001) Mortality of broiler chickens in transit: correlation with the thermal micro-environment. In: Stowell, R.R., Bucklin, R. and Bottcher, R.W. (eds) *Proceedings of the 6th International Livestock Environment Symposium,* Louisville, Kentucky, USA, 21–23 May, pp. 542–549.

Kettlewell, P.J. and Mitchell, M.A. (2001a) Comfortable ride: Concept 2000 provides climate control during poultry transport. *Resource, Engineering and Technology for a Sustainable World* 8, 13–14.

Kettlewell, P.J. and Mitchell, M.A. (2001b) Mechanical ventilation: improving the welfare of broiler chickens in transit. *Journal of the Royal Agricultural Society* 162, 175–184.

Kettlewell, P.J., Hoxey, R.P. and Mitchell, M.A. (2000) Heat produced by broiler chickens in a commercial transport vehicle. *Journal of Agricultural Engineering Research* 75, 315–326.

Kettlewell, P.J., Hampson, C.R., Green, N.R., Teer, N.J., Veale, B.M. and Mitchell, M.A. (2001a) Heat and moisture generation of livestock during transportation. In: Stowell, R.R., Bucklin, R. and Bottcher, R.W. (eds) *Proceedings of the 6th International Livestock Environment Symposium*, Louisville, Kentucky, USA, 21–23 May, pp. 519–526.

Kettlewell, P.J., Hoxey, R.P., Hampson, C.J., Green, N.R., Veale, B.M. and Mitchell, M.A. (2001b) Design and operation of a prototype mechanical ventilation system for livestock transport vehicles. *Journal of Agricultural Engineering Research* 79, 429–439.

Knowles, T.G. (1994) Handling and transport of spent hens. *World's Poultry Science Journal* 50, 60–61.

Knowles, T.G. and Broom, D.M. (1990a) The handling and transport of broilers and spent hens. *Applied Animal Behaviour Science* 28, 75–91.

Knowles, T.G. and Broom, D.M. (1990b) Limb bone strength and movement in laying hens from different housing systems. *Veterinary Record* 126, 354–356.

Knowles, T.G. and Warriss, P.D. (2000) Stress physiology of animals during transport. In: Grandin, T. (ed.) *Livestock Handling and Transport*, 2nd edn. CAB International, Wallingford, UK, pp. 385–407.

Knowles, T.G. and Wilkins, L.J. (1998) The problem of broken bones during the handling of laying hens: a review. *Poultry Science* 77, 1798–1802.

Knowles, T.G., Broom, D.M., Gregory, N.G. and Wilkins, L.J. (1993) Effect of bone strength on the frequency of broken bones in hens. *Research in Veterinary Science* 54, 15–19.

Laughlin, K.F. (1989) Computerised customer care. *International Hatchery Practice* 4, 43–45.

Meijerhof, R. (1997) The importance of egg and chick transportation. *World Poultry* 13 (11), 17–18.

Mills, D.S. and Nicol, C.J. (1990) Tonic immobility in spent hens after catching and transport. *Veterinary Record* 126, 210–212.

Misson, B.H. (1976) The effects of temperature and relative humidity on the thermoregulatory responses of grouped and isolated neonate chicks. *Journal of Agricultural Science* 86, 5–43.

Mitchell, M.A. (1999) Muscle abnormalities: pathophysiological mechanisms. In: Richardson, R.I. and Mead, G.C. (eds) *Poultry Meat Science. Poultry Science Symposium Series*, Vol. 25. CAB International, Wallingford, UK, pp. 65–98.

Mitchell, M.A. and Kettlewell, P.J. (1993) Catching and transport of broiler chickens. In: Savory, C.J. and Hughes, B.O. (eds) *Proceedings of the Fourth European Symposium on Poultry Welfare,* Universities Federation for Animal Welfare, pp. 219–229.

Mitchell, M.A. and Kettlewell, P.J. (1998) Physiological stress and welfare of broiler chickens in transit: solutions not problems! *Poultry Science* 77, 1803–1814.

Mitchell, M.A., Kettlewell, P.J. and Maxwell, M.H. (1992) Indicators of physiological stress in broiler chickens during road transportation. *Animal Welfare* 1, 91–103.

Mitchell, M.A., Kettlewell, P.J., Carlisle, A.J., Hunter, R.R. and Manning, T. (1996) Defining the optimum thermal environment for the transportation of one-day-old chicks: physiological responses during transport simulations. *British Poultry Science* 37 (Supplement), S89–S91.

Mitchell, M.A., Carlisle, A.J., Hunter, R.R. and Kettlewell, P.J. (1997) Welfare of broilers during transportation: cold stress in winter – causes and solutions. In: Koene, P. and Blokhuis, H.J. (eds) *Proceedings of the 5th European Symposium on Poultry Welfare.* WPSA, University of Wageningen and Institute of Animal Science and Health, The Netherlands, pp. 49–52.

Mitchell, M.A., Carlisle, A.J., Hunter, R.R. and Kettlewell, P.J. (2000) The responses of birds to transportation. In: *Proceedings of the World Poultry Congress,* Montreal, Canada, 22–24 August, pp. 1–14.

Mitchell, M.A., Kettlewell, P.J., Hunter, R.R. and Carlisle, A.J. (2001a) Physiological stress response modeling: application to the broiler transport thermal environment. In: Stowell, R.R., Bucklin, R. and Bottcher, R.W. (eds) *Proceedings of the 6th International Livestock Environment Symposium*, Louisville, Kentucky, USA, 21–22 May, pp. 550–555.

Mitchell, M.A., Hunter, R.R., Kettlewell, P.J. and Lowe, J. (2001b) Continuous remote monitoring of physiological signals in poultry: use in assessment of physiological stress and welfare. In: Oester, H. and Wyss, C. (eds) *6th European Symposium on Poultry Welfare*, Zollikofen, Switzerland, 1–4 September, pp. 275–277.

Nicol, C.J. and Scott, G.B. (1990) Pre-slaughter handling and transport of broiler chickens. *Applied Animal Behaviour Science* 28, 57–73.

Nilipour, A.N. (1996) Live haul, making or losing money? *World Poultry* 12 (12), 49–53.

Nilipour, A.N. (2002) Poultry in transmit are a cause for concern. *World Poultry* 18 (2), 30–33.

Quinn, A.D. and Baker, C.J. (1997) An investigation of the ventilation of a day-old chick transport vehicle. *Journal of Wind Engineering and Industrial Aerodynamics* 67/68, 305–311.

Qureshi, A.A. (1991) Losses due to dehydrated broiler chicks. *World Poultry (Misset)* 7 (4), 75–79.

Ross Breeders (1996) *Producing Quality Broiler Meat. Ross Broiler Management Manual.*

Rutter, S.M. and Randall, J.M. (1993) Aversion of domestic fowl to whole body vibratory motion. *Applied Animal Behaviour Science* 37, 69–73.

Scott, G.B. (1994) Effects of short term whole body vibration on animals with particular reference to poultry. *World's Poultry Science Journal* 50, 25–38.

Tamlyn, J. and Starr, J.R. (1987) Monitoring the environment during transportation of day olds. *International Hatchery Practice* 6 (1), 11–15.

Tanaka, A. and Xin, H. (1997a) Energetics, mortality, and body mass change of breeder chicks subjected to different post-hatch feed dosages. *Transactions of the ASAE* 40, 1457–1461.

Tanaka, A. and Xin, H. (1997b) Effects of structural and stacking configuration of containers for transporting chicks in their microenvironment. *Transactions of the ASAE* 40, 777–782.

van der Hel, W. and Henken, A.M. (1990) Give newly hatched chicks a safe flight. *Poultry International (Misset)* 6 (1), 8–9.

van der Hel, W., Verstegen, M.W.A., Henken, A.M. and Brandsma, H.A. (1991) The upper critical temperature in neonatal chicks. *Poultry Science* 70, 1882–1887.

Weeks, C. and Nicol, C. (2000) Poultry handling and transport. In: Grandin, T. (ed.) *Livestock Handling and Transport,* 2nd edn. CAB International, Wallingford, UK, pp. 363–384.

Weeks, C.A., Webster, A.J.F. and Wyld, W.M. (1997) Vehicle design and thermal comfort of poultry in transit. *British Poultry Science* 38, 464–474.

Webster, A.J.F., Tuddenham, A., Saville-Weeks, C.A. and Scott, G.B. (1993) Thermal stress on chickens in transit. *British Poultry Science* 34, 267–277.

Xin, H. (1997) Mortality and body weight of breeder chicks as influenced by air temperature fluctuations. *Journal of Applied Poultry Research* 6, 199–204.

Xin, H. and Harmon, J.D. (1996) Responses of group-housed neonatal chicks to posthatch holding environment. *Transactions of the ASAE* 39, 2249–225.

CHAPTER 31
Stunning and slaughter

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ABSTRACT

Stunning methods used for poultry include head-only electrical stunning and electrical water bath stunning with high frequency currents (usually 200–1500 Hz) that do not induce cardiac ventricular fibrillation (cardiac arrest). Stun/kill methods include application of 50 Hz sine wave AC through the whole body using either dry electrodes or electrical water baths, and exposure to gas mixtures. Captive bolts and neck dislocation are killing methods used as back-up procedures in poultry processing plants and for on-farm killing during disease outbreaks.

Electrical stunning-induced depth and duration of unconsciousness seem to depend upon the waveform and frequency of the electric current. At a given current level, increasing the frequency reduces the effectiveness of stunning and sine wave AC is more effective than pulsed DC. The time to onset of death at slaughter depends upon the blood vessels cut.

Stunning with gas mixtures does not provide adequate duration of unconsciousness and therefore stun/killing is preferred. In this regard, exposure to anoxia induced with nitrogen and/or argon appears to be the best option for bird welfare, socio-economic and environmental impact reasons.

INTRODUCTION

The European Union Treaty of Amsterdam explicitly acknowledges that animals, including poultry, are sentient beings and not agricultural products or commodities. A synonym of sentient is conscious and therefore humane slaughter regulation requires that:

- No conscious animal shall be shackled or hoisted (hung upside-down); however, poultry species are exempted for practical reasons.
- Animals must be rendered unconscious immediately prior to slaughter and they should remain so until death occurs through blood loss.
- Arteries supplying oxygenated blood to the brain, or the blood vessels from which they originate, must be severed. However, this is not mandatory in poultry (e.g. a vertebral artery alone could be severed).

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- Animals must be dead (e.g. bleeding should cease permanently) before carcass dressing (including decapitation) or any other treatment (e.g. electrical stimulation) is carried out.

Stunning methods used for poultry include head-only electrical stunning and electrical water bath stunning with high frequency currents (usually 200–1500 Hz) that do not induce cardiac ventricular fibrillation (cardiac arrest). The generic waveforms of currents are pulsed direct currents (DC) and sine wave alternating currents (AC). Stunning methods must induce a certain period of unconsciousness that is longer than the time between the end of stunning and onset of death due to blood loss. In effectively stunned poultry, the onus of preventing return of consciousness during bleeding relies on the efficiency of the slaughter procedure, i.e. prompt and accurate cutting of blood vessels supplying oxygenated blood to the brain.

Stun/kill methods, on the other hand, induce death at the point of stunning such that the necessity of neck cutting to achieve humane slaughter is eliminated. Stun/kill methods include application of 50 Hz sine wave AC through the whole body using either dry electrodes or electrical water baths, and exposure to gas mixtures.

Captive bolts and neck dislocation are killing methods used as back-up procedures in poultry processing plants and for on-farm killing during disease outbreaks.

DURATION OF UNCONSCIOUSNESS REQUIRED TO ACHIEVE HUMANE SLAUGHTER

The time to onset of death at slaughter, normally assumed on the basis of absence of pulse or cessation of bleeding, depends upon the rate of bleed-out which, in turn, depends upon the circulating blood volume and the blood vessels cut at slaughter. In birds, most of the blood supply to the brain is via the carotid arteries. However, there are other blood vessels that contribute to overall blood supply to the brain and these include the vertebral arteries that lie within the *inclusi* muscles of the neck (Gregory, 1989). Unlike mammals, there is no direct connection between the vertebral arteries and the Circle of Willis within the skull, and therefore blood from the vertebral arteries can only enter the brain via its anastomosis with the occipital artery (Gregory, 1989). This could be one of the reasons why slaughter without stunning takes longer to induce unconsciousness and brain death in poultry (Table 31.1; Gregory and Wotton, 1986). Although artificial respiration (mechanical ventilation) provided to chickens by Gregory and Wotton (1986) could have prolonged the times to onset of unconsciousness and death, similar situations would exist under processing conditions in birds that resume breathing after stunning.

Nevertheless, research carried out during the 1960s indicated that blood volume in chickens has a curvilinear relationship with body weight. For example, blood volumes of chickens weighing 1.0, 1.5, 2.0, 2.5 and 3.0 kg were estimated to be 11.6, 8.9, 7.3, 7.3 and 7.4% of body weight, respectively (Kotula and Helbacka, 1966a). Kotula and Helbacka (1966b) also found that about 50% of total blood volume is retained in the carcass (mainly capillary bed) and not bled-out at slaughter. The remaining 50% of circulating blood volume could not be drained at slaughter because various stunning methods contribute to the retention of

Table 31.1. Average (±SE) time to onset of unconsciousness and brain death following neck cut in anaesthetized and mechanically ventilated chickens.

Blood vessels cut	Times (s) to onset of	
	Unconsciousness	Brain death
Two carotid arteries	23 ± 2	163 ± 11
One carotid and one jugular	122 ± 22	302 ± 30

Source: Gregory and Wotton (1986). Brain death was determined from the time to abolition of visually evoked potentials (VEPs) in the brain.

different proportions of blood in the vital organs. For example, shooting with a captive bolt resulted in retention of the least amount and exposure to carbon dioxide resulted in retention of the highest amount of blood in the organs (heart, lungs, spleen and kidneys; see Kotula and Helbacka, 1966b). Newell and Shaffner (1950) reported that slaughter without prior stunning resulted in a significantly higher blood loss (45% of total blood volume) when compared with destruction of brain tissue with a knife (43%) or decapitation (39%). A number of other studies have also shown that, regardless of the stunning method used, the rate of bleed-out is faster when two carotid arteries and two jugular veins, instead of one carotid and one jugular vein, in the neck are severed at slaughter (Gregory and Wilkins, 1989; Raj and Gregory, 1991; Raj and Johnson, 1997).

Table 31.2 shows that cutting two carotids and two jugulars (ventral neck cut) after electrical stunning resulted in an average of 35% of the circulating blood volume being lost within 20 s of neck cutting, whereas it took twice as long to achieve a similar blood loss after cutting one carotid and one jugular (unilateral neck cut). It is worth noting that the total blood loss (45% of circulating blood volume) occurring in electrically stunned chickens is very similar to that found in birds that were slaughtered without prior stunning. Clearly, a minimum of 20 s bleed-out time causing loss of 35% of circulating blood volume in poultry would induce brain ischaemia following slaughter and, hence, prevent the return of consciousness.

Table 31.2. Effect of the blood vessels cut at slaughter on rate of bleed-out (% of blood volume).

Time (s) from neck cut	2 carotids + 2 jugulars	1 carotid + 1 jugular
10	24.75	12.13
20	35.88	24.63
30	38.75	31.25
40	41.63	34.63
50	42.88	38.13
60	43.55	39.13
70	44.00	39.75
80	44.50	40.13
90	44.88	40.38

Nevertheless, under commercial conditions, the interval between the end of stunning and neck cutting can be up to 20 s in some countries. In this situation, it can be estimated that the duration of unconsciousness induced by a stunning method should last longer than 40 s (= 20 s stun-to-neck cut plus 20 s to achieve brain ischaemia through blood loss) to avoid the return of consciousness following stunning.

Clearly, cutting two carotids and two jugulars would achieve this and, when one carotid and one jugular are to be cut at slaughter, the duration of unconsciousness induced by electrical stunning must last for 60 s (20 s stun-to-neck cut plus 40 s to induce brain ischaemia). Cutting of vertebral arteries (dorsal neck cut) alone, which is very commonly used at slaughter under commercial conditions, would require an even longer duration of unconsciousness to achieve humane slaughter. Failure to meet this requirement would result in live birds entering scald tanks.

In spite of this potential bird welfare concern, ventral neck cutting is not commonly practised under mechanized carcass processing conditions. This is mainly because some processors believe that a ventral neck cut will lead to severance of the trachea which, in turn, could lead to incomplete removal of the trachea during evisceration, which is objectionable on meat hygiene grounds. It is possible that the cartilaginous tracheal rings may snap easily during the mechanical evisceration process; however, it should also be equally possible to remove any remnants of trachea during crop removal. Ironically, presence of the trachea does not seem to be a problem for some processors, who are prepared to decapitate, instead of neck-cut, to prevent the return of consciousness in chickens whilst using inappropriate electrical stunning parameters. Owing to this and for the reason that the necks of chickens are not widely used as 'giblets' for human consumption, this apparent conflict between bird welfare and meat hygiene could be considered as unreasonable by some animal welfare authorities.

ELECTRICAL STUNNING

Constant voltage stunners are commonly used to perform electrical stunning (head-only or water bath) under commercial conditions. When a constant voltage stunner is used, the current starts to rise from zero to the maximum depending on the available supply voltage and the time it takes for the voltage to break down the total electrical resistance in the pathway (Sparrey *et al*., 1993). Owing to this, there will be a delay between the start of the application of stun and the passage of recommended current through the brain, i.e. the latency to deliver the recommended current and induction of unconsciousness. The induction of unconsciousness with low voltages/currents could be extremely painful to the birds. For example, Gallup *et al*. (1970) reported that an electric shock applied at 1.25–5.25 mA between a chicken's feet increased the duration of the tonic immobility reaction. Schutt-Abraham *et al*. (1983) reported that a current of less than 20 mA (in a water bath stunner) resulted in birds leaving the stunner squawking loudly and flapping their wings. However, prolonged (>3 s) application of very low currents may electrically immobilize chickens and prevent them from manifesting behaviours associated with pain, or could eventually stun them, which is not a humane practice.

On the other hand, with a variable voltage/constant current stunner, one

would normally expect infinite impedance in the pathway and therefore start with the maximum available voltage. It would also modulate the voltage according to the changes in the impedance during the stun. Under this situation, a constant current stunner with an output peak voltage of more than 600 V would deliver the recommended current within 0.25 s of the start of the stun (Sparrey *et al*., 1993).

The voltage necessary to deliver a fixed amount of current at a given resistance seems to be higher with a pulsed DC than sine wave AC and it also increases with increasing frequency of both waveforms (Bilgili, 1992). The frequency of currents used to stun poultry nowadays ranges from 50 to 1500 Hz. The pulse width of a DC varies widely and half or fully rectified sine waves are also used as pulsed DC to stun poultry, although their effectiveness is not known (Bilgili, 1992).

The depth and duration of unconsciousness induced with all the waveform frequency combinations have not been determined using clearly defined neurophysiological criteria in order to unequivocally recommend one stunning current that will be adequate to achieve humane slaughter under all the conditions. This problem is further confounded by the fact that the combination of, and number of, blood vessels severed in the neck at the time of slaughter may vary widely (Gregory and Wotton, 1986).

ELECTRICAL STUNNING-INDUCED UNCONSCIOUSNESS AND INSENSIBILITY

In contrast with the red meat species, electrical stunning (head-only or water bath) of poultry seldom produces grand mal epilepsy in the brain. Instead, only a small proportion of birds develop 'epileptiform' activity in the EEG following electrical stunning (Gregory and Wotton, 1987) and about 90% of birds that develop 'epileptiform' activity show low frequency (<3 Hz) polyspike or spike and wave activity. These kinds of low frequency polyspike activities in the EEG are not indicative of grand mal epilepsy and hence not always associated with unconsciousness in humans. Research so far indicates that effective electrical stunning in chickens should lead to a period of epileptiform activity and a period – at least 30 s – of profoundly suppressed or quiescent EEG immediately after epileptiform activity (Schutt-Abraham *et al*., 1983). This is mainly because an isoelectric EEG must ensue if the electrical stunning-induced epileptiform activity in the chicken's brain is indeed generalized epilepsy (Raj, 2003). Under this situation, an electrically stunned chicken showing 10 s of epileptiform activity and 30 s of quiescent or isoelectric EEG can be assumed to be unconscious and insensible for 40 s following stunning. The somatosensory evoked potentials (SEPs) in the brain are also abolished during the occurrence of a profoundly suppressed EEG in chickens (Gregory and Wotton, 1986, 1989, 1990; Raj and O'Callaghan, 2004a,b).

HEAD-ONLY ELECTRICAL STUNNING

While using a constant low voltage stunner and conventional electrodes fitted with three pins, a minimum root mean square (RMS) current of 240 mA of 50 Hz sine wave AC applied for a minimum of 5 s was found to be necessary for head-only electrical stunning of chickens (Gregory and Wotton, 1990). In this study, when

neck cutting was performed by severing all the major blood vessels in the neck within 10–15 s from the end of stun, it prevented the return of consciousness in these birds. More recent research, however, has indicated that an RMS current of 100 mA of a 50 Hz sine wave AC would be sufficient to stun chickens whilst using a pair of tongs fitted with low impedance electrodes (300 Ohms) and if stunning was performed using a variable voltage (640V peak)/constant current stunner. By way of contrast, a minimum current of 150 or 200 mA would be necessary with 400 and 1500 Hz AC, respectively, to achieve a satisfactory depth and duration of unconsciousness (Raj and O'Callaghan, 2004a).

The minimum effective current increases with the frequency, probably because the magnitude of neuronal inhibition induced by electrical stunning in chickens is determined by the duration for which the current stays at the maximum within each cycle, otherwise known as period (period = 1000/frequency) and also due to the electrical frequency-dependent nature of neurotransmitter release responses occurring in the brain (Wang and Kaczmarek, 1998). In this regard, electric currents of 50, 400 and 1500 Hz sine wave AC have periods of 20, 2.5 and 0.67 milliseconds (ms), respectively. It is therefore possible to suggest that the impact of a stunning current depends upon the period of current used and this decreases markedly when the period is below the threshold limit necessary to induce depolarization of neurones.

In another study, the impact of head-only electrical stunning of broilers with three pulse widths (5, 10 or 15 ms) of 50 Hz pulsed DC (with a period of 20 ms) delivering a constant average current of 130 mA was evaluated (A.B.M. Raj *et al.*, unpublished). The results of that study showed that increasing pulse width (i.e. increasing the duration of current ON time within each cycle) increased the percentage of birds showing epileptiform activity and increased the magnitude of EEG suppression at the maximum pulse width of 15 ms. However, at this average current level, all three pulse widths failed to induce unequivocal changes in the EEG that are normally associated with unconsciousness and insensibility following electrical stunning. The effects of stunning poultry with high frequencies of pulsed DC are very likely to be similar to those found with sine wave AC. These results also suggest that an RMS current of 100 mA of 50 Hz sine wave AC is more effective than 130 mA average current of 50 Hz pulsed DC. A possible explanation could be that, at a given RMS and average current levels, respectively, the peak-to-peak voltage is higher with an AC than with a DC.

ELECTRICAL WATER BATH STUNNING

The commercial electrical water bath stunner may contain up to 20 birds at any one time and, as birds enter and leave a stunner supplied with a constant voltage, they form a continuously changing parallel electrical circuit (Sparrey *et al.*, 1993). The voltage necessary to deliver a pre-set current seems to vary according to the depth of immersion of birds in the water bath. When this was tested using a variable voltage/constant current stunner, it was found that shallow immersion needed higher voltage than deeper immersion to deliver a pre-set constant current. Schutt-Abraham *et al.* (1992a) suggested that, in geese, such variations are due to: (i) distance between bird and the live electrode in the bath; (ii) increase in contact area between bird and electrified water; and (iii) reduction in body mass between the live and earth electrodes (shackle).

According to Ohm's law, each bird in a multiple bird water bath stunner will receive a current inversely proportional to the electrical resistance in the pathway (Sparrey *et al*., 1992). The effective electrical resistance can vary between birds, usually between 1900 and 7000 Ohms in layer hens (Schutt-Abraham and Wormuth, 1991). Most of the electrical resistance in the pathway between the electrified water bath and the earth is attributed to the poor contact between the legs and metal shackle. The electrical impedance could be reduced significantly by wetting the shackle contact area with a water spray prior to hanging the birds (Griffiths and Purcell, 1984). Although tighter-fitting shackles provide good electrical contact, the pain and suffering associated with these is likely to be severe, which can be worsened by wing flapping. Thinner metatarsal bones fitting loosely on wider metal shackles and dry scales on the legs could be attributed to relatively higher impedance. The variation in electrical resistance in the pathway and, hence, the variation in the amount of current delivered to each bird in a water bath stunner can be overcome by the installation of constant current stunners that would ensure delivery of a pre-set current to each of the birds in a water bath (Sparrey *et al*., 1993).

Schutt-Abraham *et al*. (1983) concluded that a minimum of 120 mA per chicken in a water bath would be necessary to achieve humane stunning and slaughter whilst using a 50 Hz sine wave alternating current (AC). Subsequent research showed that a minimum current of 120 mA per chicken in a water bath, delivered using either a 50 Hz sine wave AC or a 350 Hz pulsed direct current (DC), will be necessary to abolish SEPs following stunning (Gregory and Wotton, 1989, 1991). Based on these reports, it may be safe to assume that a current (RMS or average) of 120 mA delivered for a minimum of 3 s using a sine wave or a pulsed DC of up to 350 Hz would be adequate to stun chickens.

In a recent study, the effectiveness of water bath electrical stunning of chickens with a constant RMS current of 100 mA delivered for 3 s using 100, 200, 400, 800 and 1500 Hz sine wave AC was investigated (Raj and O'Callaghan, 2004b). The results indicated that stunning of chickens with a constant RMS current of 100 mA delivered for 3 s using 100 or 200 Hz induced epileptiform activity immediately followed by a profoundly suppressed EEG lasting for up to 50 s. The SEPs were also abolished during the occurrence of suppressed EEGs. It was therefore suggested that electrical water bath stunning of chickens with a RMS current of 100 mA delivered using 100 or 200 Hz induced a satisfactory depth and duration of unconsciousness. However, both the carotid arteries in the neck must be severed at slaughter to prevent return of consciousness. By contrast, water bath electrical stunning of chickens with a RMS current of 100 mA delivered for 3 s using 400, 800 and 1500 Hz failed to induce epileptiform activity and EEG suppression in some birds and the SEPs were also retained in the majority of chickens. It was therefore suggested that stunning chickens with a RMS current of 100 mA delivered using these high frequencies (>200 Hz) does not fulfil the criteria set to protect the welfare of birds at slaughter. The implication of these results is that the minimum effective stunning current increases with frequency (Table 31.3).

Table 31.3. Minimum recommended RMS currents (mA per chicken) for water bath stunning.

Frequency (Hz)	Current (mA)
Up to 200 Hz	100
200–400 Hz	150
400–1500 Hz	200

ELECTRICAL STUN/KILL METHODS

Electrical Stun/Kill in Water Bath

The only difference between the electrical water bath stunning and electrical stun/kill in a water bath is the frequency of the electric current employed. A 50 Hz sine wave (full or clipped) AC has been proven to be effective in inducing cardiac ventricular fibrillation at stunning in a water bath (Gregory *et al.*, 1995). When a 50 Hz sine wave AC is used, the current necessary to induce cardiac arrest in 99% of chickens is 148 mA per chicken in a water bath (Gregory and Wotton, 1987).

Electrical Stun/Kill Using Dry Electrodes

The Silsoe Research Institute in the UK has developed a prototype electrical stun/kill system recently (without shackling of live birds). This system involves head-only electrical stunning for 1 s with 150 mA of 50 Hz AC immediately followed by head-to-body (vent) application of the same current for 1 s. The results of a study involving this prototype indicated that an electrical stun/kill technique can be better than the water bath system on animal welfare and carcass and meat quality grounds (Raj *et al.*, 2001).

GAS STUNNING

The main objective of gas stunning is to alleviate the pain and suffering associated with the shackling of conscious poultry under water bath stunning and killing systems. Gas stunning of poultry in their transport containers will eliminate the need for live bird handling at the processing plant and all the problems associated with the electrical stunning. Gas stunning poultry on a conveyor would eliminate the problems associated with the electrical water bath stunning. Under these circumstances, since birds will be stunned in large numbers and they all will have to be shackled and neck cut, the interval between the end of exposure to gas mixture and neck cutting is likely to be long, at least for some birds. Therefore, the duration of unconsciousness induced during batch stunning of poultry will have to be longer than that required under electrical stunning situations in order to prevent return of consciousness either prior to neck cutting or during bleeding. For welfare reasons, since the induction of unconsciousness with gas mixtures is a gradual process, the gas mixture should be non-aversive and the induction of unconsciousness should not be distressing to the birds.

Scientific investigations so far have addressed this concern by evaluating:

- aversive reactions occurring during initial exposure;
- respiratory discomfort prior to loss of consciousness;
- time to loss of consciousness;
- duration of unconsciousness.

It has been reported that three out of eight hens tested avoided a feeding chamber to obtain food and water when it contained 47% by volume of carbon dioxide in the atmosphere (Raj, 1996). By contrast, six out of six hens spontaneously entered the feeding chamber containing 90% argon in air with 2% by volume of residual oxygen, and were killed with the gas. The conclusion was that anoxia is not aversive to poultry. Woolley and Gentle (1988) exposed chickens to decreasing concentrations of oxygen created by using nitrogen and reported that at no time during the anoxic killing did the birds show any marked respiratory distress nor was there any of behaviour suggestive of distress. Exposure of poultry to carbon dioxide gas mixtures induces signs of respiratory distress (gasping and head shaking) prior to loss of consciousness. It has been suggested that the addition of oxygen to carbon dioxide may not be beneficial to bird welfare (Raj *et al.*, 1998). This is based on the observation that, during the induction phase, birds that were exposed to a mixture of 50% carbon dioxide and 50% oxygen behaved (i.e. showed signs of respiratory distress) in a similar way to those exposed to 50% by volume of carbon dioxide in air (Zeller *et al.*, 1988).

The times to loss of consciousness, as determined from the time to abolition of SEPs, during exposure of hens to various gas mixtures, are presented in Table 31.4. Evidently, exposure to carbon dioxide–argon mixture leads to a relatively more rapid onset of unconsciousness than that which occurs with argon alone. However, birds do not show gasping and head shaking during exposure to argon, and therefore a slightly longer time to onset of unconsciousness is not a welfare concern. By contrast, birds would have to endure severe respiratory distress induced with a high concentration of carbon dioxide for a considerable period of time (e.g. 26 s). Exposure of broilers for longer than 2 min to a mixture of 40% carbon dioxide, 30% oxygen and 30% nitrogen failed to abolish SEPs in all the chickens (Raj *et al.*, 1998).

The feasibility of using various gas mixtures for batch stunning of poultry under commercial conditions has been evaluated to some extent. When using argon as the anoxic agent, 5% by volume of residual oxygen and 2 min exposure time failed to stun the chickens (Raj and Gregory, 1990). Raj and Gregory (1990) found that chickens could be stunned with an exposure time of 2 min to 2% by volume of

Table 31.4. Time (s) to loss of SEPs in hens during exposure to gas mixtures (mean ± SEM).

90% argon in air	49% carbon dioxide in air	31% carbon dioxide and 60% argon in air	30% carbon dioxide and 45% argon in air
29 ± 2	26 ± 3	19 ± 2	17 ± 3

Source: Raj *et al.* (1992a,b).

residual oxygen; however, the chickens responded to comb pinching at 15 s after being returned to atmospheric air. Evidently, 15 s of unconsciousness would not be sufficient to avoid return of consciousness and sensibility either before neck cutting or during bleeding.

Kotula *et al*. (1957) recommended that chickens should be exposed for 75 s to 33–36% by volume of carbon dioxide in air to stun them. The time interval between the end of exposure to carbon dioxide and neck cutting was not reported in this study; however, it is stated that cutting one carotid artery and one jugular vein at slaughter resulted in wing flapping during bleeding in most of the birds. Although the state of consciousness in these birds was not measured, the authors state that the birds were unconscious when they flapped their wings. Another study indicated that during exposure to various concentrations of carbon dioxide it would be difficult to effectively stun all the poultry without inducing death in some birds and the duration of unconsciousness induced with the stun can be very short in some birds (Zeller *et al*., 1988). Exposure of chickens to 45% by volume of carbon dioxide in air for 2 min has been reported to have resulted in death in a majority of the birds but the survivors showed a positive response to comb pinching as early as 26 s after returning to atmospheric air (Raj and Gregory, 1990). It is worth noting that carbon dioxide-induced analgesia may last longer than the period of unconsciousness and, therefore, response to comb pinching may not be a reliable indicator of return to consciousness (Zeller *et al*., 1988). Nevertheless, 26 s of unconsciousness would not be sufficient to avoid return of consciousness and sensibility either before neck cutting or during bleeding.

Exposure of chickens for 2 min to a mixture of argon (could also be nitrogen or mixtures of argon and nitrogen) and 10, 20 or 30% by volume of carbon dioxide with 5% by volume of residual oxygen has been reported to result in death in 76, 99 and 100% of birds (Raj *et al*., 1992c). The exposure time required to stun, rather than kill, poultry and the duration of unconsciousness induced with these gas mixtures are not known.

Exposure of chickens for 2 min to a mixture of 40% by volume of carbon dioxide, 30% by volume of oxygen and 30% by volume of nitrogen resulted in death in three out of 17 birds, failed to abolish SEPs in some birds, and returning the survivors to atmospheric air resulted in recovery of response to comb pinching as early as 30 s (Raj *et al*., 1998). Nevertheless, 30 s of unconsciousness would not be sufficient to avoid return of consciousness and sensibility either before neck cutting or during bleeding.

Moreover, if crates and conveyors are used for gas stunning, poultry will be leaving the stunning units in large groups or numbers. At the exit, the unconscious poultry will have to be shackled before neck cutting can be performed. Under this situation, the total time interval between the end of exposure to a gas mixture and onset of death after neck cutting is likely to be longer than the duration of unconsciousness induced with a gas mixture.

There is no scientific evidence concerning the time to onset of death due to bleeding after gas stunning in poultry. However, considering the prolonged interval between gas stunning and shackling and the time it takes for bleeding to induce brain ischaemia in poultry, it is doubtful whether return of consciousness could be avoided in gas-stunned poultry.

GAS MIXTURES FOR STUN/KILL

The only difference between gas stunning and gas stun/kill is that the birds are exposed to gas mixtures until they are dead. Therefore, any delay in neck cutting and the blood vessels cut becomes irrelevant. It is emphasized that, since one of the objectives of stun/kill with gas mixtures is to alleviate the pain and suffering associated with the shackling of conscious poultry under water bath stunning and killing systems, this method is best limited to birds contained in crates or on conveyors only.

Gas Mixtures Approved for Stun/Killing Poultry in the UK

- A minimum of 2 min exposure to argon, nitrogen or other inert gases, or any mixture of these gases, in atmospheric air with a maximum of 2% oxygen by volume.
- A minimum of 2 min exposure to any mixture of argon, nitrogen, or other inert gases with atmospheric air and carbon dioxide provided that the carbon dioxide concentration does not exceed 30% by volume and the oxygen concentration does not exceed 2% by volume.

Under commercial poultry processing conditions in Europe and the USA, a mixture containing 80% nitrogen and 20% argon or carbon dioxide is being used for broiler chickens. In both the mixtures, a residual oxygen level of less than 2% by volume is maintained and birds are exposed for a minimum of 2 min. In this system, crates containing poultry are carried through a tunnel containing one of the approved gas mixtures.

STUN/KILL WITH CAPTIVE BOLTS

Mechanical devices have been developed specifically to kill poultry, and these can be penetrating or non-penetrating captive bolts that are fired using either cartridges or compressed air. Spring-loaded captive bolts have also been evaluated for killing poultry in Germany (Schutt-Abraham *et al.*, 1992b).

Research carried out in The Netherlands involving broiler chickens and a penetrating bolt with a diameter of 5 mm and a length of 25 mm (Hillebrand *et al.*, 1996), showed that captive bolt shooting can be effective in inducing unconsciousness in birds.

More recently, a pneumatically operated penetrating captive bolt was evaluated for broilers. The results indicated that the bolt must be fired perpendicular to the skull and the ideal parameters should be a minimum of 6 mm bolt diameter delivering an impact energy of not less than 21 J and a penetration depth of 10 mm (Raj and O'Callaghan, 2001). In these broilers, loss of visually evoked potentials (VEPs) occurred immediately after shooting. Broilers shot with these parameters died immediately but showed very severe wing flapping. Furthermore, it was found that, unless the bolt was fired perpendicular (at a right-angle) to the surface of the skull, it did not always stun or kill the birds – a disconcerting feature from a welfare point of view.

EUTHANASIA OF POULTRY

Chickens are also killed in large numbers at various stages because they are of wrong sex, at the end of their production cycle with no market demand for hen meat, or if there is an outbreak of disease. Considering sex ratio in chickens, chicks are regularly killed in hatcheries (soon after sexing) in large numbers equalling the number of layer hens reared for egg production at any one time anywhere in the world. It is therefore hardly surprising to note that the Humane Slaughter Association (HSA, 2002) has dedicated a separate publication to dealing with the humane killing of unwanted chicks. Two humane methods are recommended by the HSA, namely, immediate mechanical destruction (IMD) or maceration and exposure to anoxic gas mixtures. For IMD purposes, only macerators specifically designed for the disposal of chicks that have rotating blades turning at least 6000 or more revolutions per minute (rpm) must be used. There are at least two types of devices used for macerating unwanted chicks in hatcheries. A crushing type has either one roller that rotates against a solid projection, or two contra-rotating rollers. The chicks are crushed and killed in a narrow, restricted gap between the rollers or projections. The 'knife-type' design has rapidly rotating blades, which effectively macerate the chicks. Two minutes exposure to argon and/or nitrogen with less than 1% residual oxygen, a mixture containing 30% by volume of carbon dioxide in argon and/or nitrogen with 2% by volume of residual oxygen is found to be adequate to kill unwanted chicks (Raj and Whittington, 1995). Ideally, nitrogen could be extracted from air, using nitrogen separation plants, and the residual oxygen could be used in the brooders. Chicks could be killed with a minimum of 90% by volume of carbon dioxide in air; however, the HSA (2002) guidelines disapprove of this method on bird-welfare grounds.

These gas mixtures could also be used to kill end-of-lay chickens on the farm. The use of macerators for adult birds, however, may not be practical or bird-welfare friendly. This is mainly because, unlike newly hatched chicks, adult birds can fly and avoid being caught between the rotating blades or projections of a macerator and hence could suffer potentially painful injuries, or the death may not be instantaneous. Therefore, adult chickens would have to be anaesthetized prior to maceration on bird-welfare grounds.

On the other hand, the portable equipment required for on-farm killing of chickens with gas mixtures or an electric current is being manufactured in Europe and, when implemented fully, would benefit bird welfare. However, a potential welfare as well as practical problem with the end-of-lay hens is that they are reared using different husbandry systems and not all the systems are conducive to catching and crating without compromising bird welfare. Therefore, any system to be developed in the future should also take into account the facilities necessary for the depopulation of chickens with the minimum of distress to the birds and operatives. On the other hand, when carcasses are not intended for human consumption, layer hens should ideally be killed in the rearing environment so that carcasses can be removed. However, the feasibility of achieving this under the various husbandry systems currently in use is yet to be investigated.

SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACTS

Electrical stunning and stun/kill methods are the cheapest options. Carbon dioxide could be cheaper than nitrogen or argon in some countries; however, it is a known greenhouse gas. In comparison with electrical methods, killing chickens with gas mixtures results in better carcass and meat quality and the potentially increased revenue should compensate for higher capital and running costs associated with the latter.

REFERENCES

Bilgili, S.F. (1992) Electrical stunning of broilers – basic concepts and carcass quality implications: a review. *Journal of Applied Poultry Science* 1, 135–146.

Gallup, G.G., Nash, R.F., Potter, R.J. and Donegan, N.H. (1970) Effect of varying conditions of fear on immobility reactions in domestic chickens (*Gallus gallus*). *Journal of Comparative and Physiological Psychology* 73, 442–445.

Gregory, N.G. (1989) Stunning and slaughter. In: Mead, G.C. (ed.) *Processing of Poultry*. Elsevier Applied Science, London, pp. 31–63.

Gregory, N.G. and Wilkins, L.J. (1989) Effect of slaughter on bleeding efficiency in chickens. *Journal of Science of Food and Agriculture* 47, 13–20.

Gregory, N.G. and Wotton, S.B. (1986) Effect of slaughter on the spontaneous and evoked activity of the brain. *British Poultry Science* 27, 195–205.

Gregory, N.G. and Wotton, S.B. (1987) Effect of electrical stunning on the electroencephalogram in chickens. *British Veterinary Journal* 143, 175–183.

Gregory, N.G. and Wotton, S.B. (1989) Effect of electrical stunning on somatosensory evoked potentials in chickens. *British Veterinary Journal* 145, 159–164.

Gregory, N.G. and Wotton, S.B. (1990) An evaluation of the effectiveness of handheld stunners for stunning chickens. *Veterinary Record* 126, 290–291.

Gregory, N.G. and Wotton, S.B. (1991) Effect of a 350 Hz DC stunning current on evoked responses in the chicken's brain. *Research in Veterinary Science* 50, 250–251.

Gregory, N.G., Wilkins, L.J., Wotton, S.B. and Middleton, A.L.V. (1995) Effects of current and waveform on the incidence of breast meat haemorrhages in electrically stunned broiler chicken carcases. *Veterinary Record* 137, 263–265.

Griffiths, G.L. and Purcell, D.A. (1984) A survey of slaughter procedures used in chicken processing plants. *Australian Veterinary Journal* 61, 399–401.

Hillebrand, S.J.W., Lambooij, E. and Veerkamp, C.H. (1996) The effects of alternative electrical and mechanical stunning methods on haemorrhaging and meat quality of broiler breast and thigh muscles. *Poultry Science* 75, 664–671.

HSA (Humane Slaughter Association) (2002) *Codes of Practice for the Disposal of Chicks in Hatcheries*, 2nd edn. Humane Slaughter Association, Wheathampstead, UK.

Kotula, A.W., Drewniak, E.E. and Davis, L.L. (1957) Effect of carbon dioxide immobilisation on the bleeding of chickens. *Poultry Science* 36, 585–589.

Kotula, A.W. and Helbacka, N.V. (1966a) Blood volume of live chickens and influence of slaughter technique on blood loss. *Poultry Science* 45, 684–688.

Kotula, A.W. and Helbacka, N.V. (1966b) Blood retained by chicken carcasses and cut-up parts as influenced by slaughter method. *Poultry Science* 45, 404–410.

Newell, G.W. and Shaffner, C.S. (1950) Blood loss by chickens during killing. *Poultry Science* 29, 268–271.

Raj, A.B.M. (1996) Aversive reactions of turkeys to argon, carbon dioxide and a mixture of carbon dioxide and argon. *Veterinary Record* 138, 592–593.

Raj, A.B.M. (2003) A critical appraisal of electrical stunning in chickens. *World's Poultry Science Journal* 59, 89–98.

Raj, A.B.M. and Gregory, N.G. (1990) Investigation into the batch stunning/killing of chickens using carbon dioxide or argon-induced hypoxia. *Research in Veterinary Science* 49, 364–366.

Raj, A.B.M. and Gregory, N.G. (1991) Efficiency of bleeding of broilers after gaseous or electrical stunning. *Veterinary Record* 128, 127–128.

Raj, A.B.M. and Johnson, S.P. (1997) Effect of the method of killing, interval between killing and neck cutting and blood vessels cut on the blood loss in broilers. *British Poultry Science* 38, 190–194.

Raj, A.B.M. and O'Callaghan, M. (2001) Evaluation of a pneumatically operated captive bolt for stunning/killing broiler chickens. *British Poultry Science* 42, 295–299.

Raj, A.B.M. and O'Callaghan, M. (2004a) Effect of amount and frequency of head-only stunning currents on the electroencephalogram and somatosensory evoked potentials in broilers. *Animal Welfare* (UFAW) *Journal* (in press).

Raj, A.B.M. and O'Callaghan, M. (2004b) Effects of electrical water-bath stunning current frequencies on the spontaneous electroencephalogram and somatosensory evoked potentials in hens. *British Poultry Science* 45 (in press).

Raj, A.B.M. and Whittington, P.E. (1995) Euthanasia of day-old chicks with carbon dioxide and argon. *Veterinary Record* 136, 292–294.

Raj, A.B.M., Wotton, S.B. and Gregory, N.G. (1992a) Changes in the somatosensory evoked potentials and spontaneous electroencephalogram of hens during stunning with a carbon dioxide and argon mixture. *British Veterinary Journal* 148, 147–156.

Raj, A.B.M., Wotton, S.B. and Whittington, P.E. (1992b) Changes in the spontaneous and evoked electrical activity in the brain of hens during stunning with 30 per cent carbon dioxide in argon with 5 per cent residual oxygen. *Research in Veterinary Science* 53, 126–129.

Raj, A.B.M., Gregory, N.G. and Wilkins, L.J. (1992c) Survival rate and carcase downgrading after the stunning of broilers with carbon dioxide-argon mixtures. *Veterinary Record* 130, 325–328.

Raj, A.B.M., Wotton, S.B., McKinstry, J.L., Hillebrand, S.J.W. and Pieterse, C. (1998) Changes in the somatosensory evoked potentials and spontaneous electroencephalogram of broiler chickens during exposure to gas mixtures. *British Poultry Science* 39, 686–695.

Raj, A.B.M., Wilkins, L.J., O'Callaghan, M. and Phillips, A.J. (2001) Effect of electrical stun/kill method, interval between killing and neck cutting and blood vessels cut on blood loss and meat quality in broilers. *British Poultry Science* 42, 51–56.

Schutt-Abraham, I. and Wormuth, H.-J. (1991) Anforderungen an eine tierschutzgerechte elektrische Betaubung von Schlachtegeflugel. *Rundeschau fur Fleischhygiene und Lebensmitteluberwachung* 43, 7–8.

Schutt-Abraham, I., Wormuth, H.-J. and Fessel, J. (1983) Electrical stunning of poultry in view of animal welfare and meat quality. In: Eikelenboom, G. (ed.) *Stunning of Animals for Slaughter*. Martinus Nijhoff, The Hague, pp. 187–196.

Schutt-Abraham, I., Knauer-Kraetzl, B. and Wormuth, H.-J. (1992a) Effects of some stunning conditions on the currents obtained during the electrical stunning of geese. *Fleischwirtchaft* 72, 298–300.

Schutt-Abraham, I., Knauer-Kraetzel, B. and Wormuth, H.-J. (1992b) Beobachtungen bei der Bolzenschussbetaubung von Kaninchen. *Berliner-und-Munchener-Tierarztliche-Wochenschrift* 105, 10–15.

Sparrey, J.M., Kettlewell, P.J. and Paice, M.E. (1992) A model of current pathways in electrical waterbath stunners used for poultry. *British Poultry Science* 33, 907–916.

Sparrey, J.M., Kettlewell, P.J., Paice, M.E.R. and Whetlor, W.C. (1993) Development of a constant current water bath stunner for poultry processing. *Journal of Agricultural Engineering Research* 56, 267–274.

Wang, L.-Y. and Kaczmarek, L.K. (1998) High frequency firing helps replenish readily releasable pool of synaptic vesicles. *Nature* 394, 384–388.

Woolley, S.C. and Gentle, M. (1988) Physiological and behavioural responses of the domestic hen to hypoxia. *Research in Veterinary Science* 45, 377–382.

Zeller, W., Mettler, D. and Schatzmann, U. (1988) Studies into the stunning of slaughter poultry with carbon dioxide. *Fleischwirtschaft* 68, 1308–1312.

PART IV
Outcomes

CHAPTER 32
Priorities

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INTRODUCTION

The meeting on which this volume reports presented a broad review of issues relating to the welfare of laying hens. This final chapter will identify some of the common themes and priorities that emerged in that review, and which can be deduced from the broad context in which poultry welfare must now be considered. There was, in fact, a considerable degree of consensus among the very diverse delegates at the meeting: it was never questioned, for example, that hen welfare is a matter of serious concern and that it is appropriate to examine ways in which welfare can be safeguarded and improved. This does not mean, of course, that there was unquestioning unanimity on details or on priorities. As one example of variation in emphasis, Keeling discussed resource use in relation to nesting, perching and dust bathing. She called attention to the fact that we should be concerned for the welfare of all individuals with the memorable question: 'You can please some of the hens all the time, and all of the hens some of the time, but can you please all of the hens all of the time?' By contrast, while Faure also mentioned individual variation in use of resources, his response was to ask 'So what?', reminding us that we often do not know the welfare implications of individual variation, and there may indeed be no such implications. This was a difference in emphasis between two scientists. Unsurprisingly there were also differences between representatives of different professions, such as producers and welfarists; but it remains true that these were differences of emphasis rather than major disagreements.

INDIVIDUALS AND GROUPS

The issue of individual variation raised by Keeling and Faure was one aspect of a theme common to many of the contributions: the balance to be drawn between consideration of individual birds and of groups. Jorêt stressed the fact that producers operate commercial businesses, so while they may be concerned for individual hens, they must in general be more concerned with the whole flock, including the economics of performance at a flock level. A similar approach was taken by Thaxton in relation to disease, suggesting that disease prevention and

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treatment must be planned for groups of birds, as it is not practical to deal with individuals on this basis. A counterpoint to this was offered by Humphrey, however, who demonstrated that understanding of disease and all its correlates – including problems for food safety – can sometimes only be achieved by studying individuals. Humphrey's team recorded shedding of salmonella in the eggs of individual hens, and showed that flockmates tended to shed salmonella on the same day. There must therefore be environmental factors involved in the transmission of this disease and in the production of contaminated eggs.

MacLeod emphasized that while hens are usually fed a single compound diet, individuals have different nutritional requirements. Choice feeding might improve the welfare of individual hens, and also reduce nitrogen excretion by those birds that currently take in an excess. In a different context, though, Muir explained that focusing on individuals may cause problems for both individuals and groups: genetic selection of individuals for production has increased aggressiveness and injurious pecking behaviour. Breeders are beginning to base selection on groups of siblings, reducing injurious pecking and thereby improving both welfare and production.

WORK IN COMMERCIAL CONDITIONS

Muir also pointed out that the conditions in which birds are housed for selection are different from those during production, and performance in the former is often a poor predictor of that in the latter. Similarly, scientific studies in the laboratory may have limited application to commercial conditions, usually considerably different. There is a need for more studies in commercial conditions. For example, Parsons avowed that experience is vital in limiting mortality in a commercial egg production enterprise, and it would be valuable to know exactly why that is true – what beneficial changes result for managers and birds when the managers are experienced. However, it must be noted that achieving proper control of all the relevant variables for a scientific study on a commercial farm is extremely difficult.

NEW INFORMATION

The meeting was intended to highlight new information on hen welfare. Some such information emerged from traditional behavioural studies; for example, both Keeling and Newberry reported that housing chickens with perches reduces cannibalism. However, scientific progress is increasingly coming from cross-disciplinary thinking. The contribution of different scientific disciplines to our understanding of welfare was evident in papers such as those presented by Prescott (opthalmics), Nicol (cognitive science), Rutherford (advanced mathematical analysis) and Green (aerodynamics). This trend also demonstrates an increasing maturity apparent in the scientific study of welfare. Not surprisingly, questions arose during the meeting as well as answers, and some of these may require multidisciplinary study. As one example, Thaxton mentioned measurement of corticosterone in egg yolks. Yolk is deposited in the ovum in daily layers, so this raises the question of whether corticosterone could be measured in different layers to give a history of the hen's stress levels over several days.

Improvement of welfare requires not just scientific understanding but practical application, and cross-disciplinary thinking is also important for this. Muir's contribution reported progress that has been made by interaction with industry. Pritchard explained that for political action, ethical considerations must be taken into account as well as scientific ones, and Savory's results supported this by showing that behavioural studies of hens in floor pens do not produce a definitive recommendation on space allowance. Economics must also be considered, at various levels. Bowles warned that international trade is likely to threaten the competitiveness of egg production in the European Union and hence the ability to safeguard hen welfare. This possibility was strengthened by Elson's analysis of the performance of different systems in monetary terms. However, Hinrichs gave some cause for optimism in a study that found production to be almost as cheap in enriched cages as in conventional ones. Lastly, economics also involves sociological considerations, and Parrott's study of consumer perspectives reminds us that consumers have a general expectation of assurances on food safety and farm animal welfare. This is an expectation that the livestock industry and those working with the industry will increasingly need to address.

HUSBANDRY SYSTEMS

Many papers presented at the meeting compared different husbandry systems for laying hens, and it is apparent that all systems have both advantages and disadvantages for welfare. There is no consensus about which system is best for welfare, partly because different people emphasize different aspects: for example, some emphasize the physical aspects of welfare, while others consider behaviour to be more important. Thus Parsons reported a pattern of higher mortality in non-cage systems than in cages and some delegates considered this a critical indicator for welfare, but several speakers placed more emphasis on the behavioural restriction of cages and the increased freedom in other systems. There was at least consensus in the fact that no one spoke in favour of retaining conventional, barren laying cages on welfare grounds, even if monetary considerations may still support that system. It is also important to note that the 1999 European Directive mandates measures to improve welfare in all systems, both cages and alternatives.

AREAS FOR FUTURE RESEARCH

Research will continue to be necessary for the understanding and improvement of hen welfare, both within science and in collaboration between scientists, industry and the other disciplines mentioned above, such as politics, economics and sociology. One priority may be identified in the need for new thinking in the economics of animal production. Livestock agriculture affects many areas of public concern, including animal welfare and the environment, and it can be argued that we must find ways of moving away from competition as the main determinant of agricultural prices and therefore of agricultural practices.

That approach is part of a general tendency in research that is likely to continue increasing, a concentration on sustainability. Sustainability is needed in monetary terms for producers to stay in business and care for animals. It is needed for

our environment and for other vital issues such as food safety, and those involve proper animal care. Another priority that may be recognized in agricultural research, then, is that it will become focused more on the animals themselves than on production parameters.

Two possible examples may illustrate these priorities. First, more consideration could be given to increasing the longevity of laying hens. Attempts are being made to find methods of induced moulting that do not compromise welfare, and if these are successful it seems appropriate to keep hens for a productive life of several years rather than culling them after 1 year, with all the resultant problems of slaughter and carcass disposal. Second, the use of hybrids for egg production is standard, but can be challenged. If productive, true-breeding strains of hens could be established instead, this would allow much more adaptation of birds to their environment, and greater application of genetic selection to ameliorate many welfare problems.

Conferences like the one reported here help to develop a vision for agriculture in the future that will be sustainable for our animals, our environment and ourselves.

PART V
Poster abstracts

POSTER 1
Sustainable development of egg production systems: it's not only welfare that counts

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Public concern for animal welfare has stimulated the development of alternative, 'animal-friendly' production systems, including enriched cages, aviary and free-range systems for laying hens. Societal criticism has also resulted in new legislation, favouring the application of those animal-friendly production systems.

We are developing a methodology to assess the contribution of various production systems to sustainable development based on combined economic, ecological and societal performance. The methodology comprises the following steps:

- *Stakeholder analysis:* In a workshop with stakeholders, important matters are discussed.
- *Sustainability issues:* Sustainability issues emerge from the stakeholder analysis after further discussions with experts and a literature review.
- *Sustainability indicators:* For each issue, a suitable sustainability indicator (SI) is selected according to these criteria: *relevance*, *simplicity*, *sensitivity* and *reliability*, *the ability to determine trends or target values*, and *data accessibility*. Selection resulted in the following SIs: land and energy use; global warming, acidification and eutrophication potential; deviations from standard production curves; total percentage second-quality eggs; *Salmonella* (Se/St) contamination; net farm income per FTE; medicine use; mortality rate; Animal Needs Index (TGI); availability of knowledge; percentage of farmers experiencing respiratory or back problems; working hours.
- *Final assessment:* A clear presentation of the results of all indicators.

It was concluded that:

- To assess the contribution of various systems to sustainable development of egg production, not only welfare but a wide variety of economic, ecological and societal issues have to be considered.
- Weighting factors for different issues have to be assessed by individuals or groups, because it is impossible to make a general judgement.

POSTER 2
Laying hens in enriched cages: economic experience in Germany

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From 2012 onwards, conventional battery cages will be banned in all EU countries. Will the dominating demand for cheap eggs (more than 80%) be served with imports after that, or will the production in enriched cages be competitive?

From 2000 to autumn 2003, an inter-disciplinary team evaluated six pilot farms keeping hens in enriched cages. The economic part focused on competitiveness indicated by the average total costs per 1000 eggs. The reference was egg production in conventional cages, preferably in the same enterprise, which was available for four farms.

- The laying performance was as high as the reference or better.
- So were the average costs for pullet, feed, medication, energy and water.
- The investment costs were higher, due to increased space requirement.
- The labour input also increased, but the difference was declining.
- The total cost increase per 1000 eggs was between –0.2 and 2.9 (<6%) EUR.

Even after a short time of experience, eggs can be produced in enriched cages at costs almost as low as in conventional cages. There is no alternative system in view which is as competitive in the large market segment of cheap eggs.

POSTER 3
Non-invasive monitoring of stress in the laying hen: a vocalization analysis approach

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In this work a general methodology is presented in order to overcome the disadvantages of the common stress measurements, such as cost and labour intensity, invasivity and the lack of real-time information about the stress status of the animals.

In spite of the disadvantages mentioned in the scientific literature, the corticosterone concentration is accepted as a standard physiologically relevant method to determine the hen's stress level. If a desired alternative physiologically relevant stress-level estimator is related to the corticosterone concentration, a generally acceptable objective quantitative measure will be obtained. The next step is to attempt to broaden this into a general methodology (i.e. suitable regardless of the nature of the stressor). In addition, the ideal method should be non-invasive and should allow for continuous, online monitoring.

In the literature, non-verbal vocalizations are shown to communicate emotions in animals. Hence vocalization analysis may provide a useful tool for evaluating the emotional state of an animal. The important advantage of this approach is that it is a relatively objective, non-invasive and online monitoring of emotions related to environmental changes. The listed characteristics match well with the desirable criteria for an alternative stress-level monitor. So if vocalization or vocalization features change in response to an arbitrary stressor, vocalization analysis appears to be a useful objective and quantitative alternative to the stress-level measurement based on blood sampling.

Vocalizations are species-specific. Due to its economic importance, the manageability and the invasive nature of deliberately eliciting stress and blood sampling, this work focuses on the laying hen. Since the laying hen is an adult animal, age-induced changes in vocalizations need not be considered.

POSTER 4
Studies of fear and stress-related traits in Spanish breeds of chicken

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The effects of several factors related to welfare levels on the heterophil:lymphocyte ratio (an indicator of stress) and the tonic immobility duration (an indicator of fear) were studied in different chicken populations (traditional Spanish breeds and White Leghorn). In addition, we aimed to estimate the heritability of both these traits and determine whether there were heterotic effects or genotype × treatment interactions. The factors analysed included: supplemental zinc oxide, corticosterone, cholesterol, tocopherol, niacin, or lactic acid in the diet, fasting, heat, cold, trapnest, dust bathing, plumage condition, handling, mating ratio, photoperiod, pink eggshells, internal inclusions, and sexual maturity. Heterophil:lymphocyte ratio was significantly decreased by dust bathing, good plumage condition and supplemental tocopherol or niacin in the diet, whereas it was significantly increased by supplemental lactic acid, and associated with pink eggshells, internal inclusions, sexual maturity (in hens) and 1:1 mating ratio (in hens). Tonic immobility duration was significantly shorter with fasting, supplemental zinc oxide, heat, cold (one breed), trapnest, pink eggshells, internal inclusions, sexual maturity (in hens) and 1:1 mating ratio (in cocks), and significantly longer with supplemental corticosterone, sexual maturity (in cocks), good plumage condition, upright handling and 23L:1D photoperiod. The heritability was high for heterophil:lymphocyte ratio and number of heterophils and lymphocytes, and intermediate for tonic immobility duration. There was negative heterosis for both traits, and significant interactions with supplemental cholesterol in the diet.

POSTER 5
Control of landing flight in laying hens: what are the effects of domestication?

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The ability of laying hens to control landing flight is important for the design of perchery and aviary systems. Ten Lohmann Brown layers were video-recorded while flying between two perches. The horizontal distance between the perches was 60, 80 or 115 cm, and one perch was 20 cm above or below the other. Landing outcomes (perfect, clumsy or missed) were measured, together with the series of *eye* positions during each flight. At slaughter, wing loadings (weight/wing area) were calculated. All missed or clumsy landings (n=5) occurred after flights of 115 cm. Hens always bobbed their heads with a regular rhythm during flight. Take-off trajectories, and the orientation of hens' heads at take-off, were closely related to the position of the landing perch. At the point when the feet first contacted the landing perch, variation in the vertical, but not the horizontal, distance of hens' heads from the landing perch increased with increasing flight distance. This shows accumulating error in controlling height above the perch but not in the timing of foot extension. Average wing loading was approximately 75% greater than would be expected for a typical member of the family Phasianidae of the same weight. The results give no indication that domestication has affected the perceptual components of flight control. Decreasing accuracy of landing with increasing flight distance arises from the adverse effects of high wing loading on the ability to generate lift and so to control height.

POSTER 6
Applying fractal analysis to laying hen behaviour

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The value of fractal analysis of behaviour was investigated as a non-invasive indicator of stress in laying hens. Fractal analysis provides a measure of 'hidden information' in the temporal organization of behaviour that may alter when gross features of behaviour, such as mean durations or frequencies, do not. We use the fractal method of detrended fluctuation analysis (DFA), which produces a value that varies along a continuum from a completely random pattern to increasing degrees of autocorrelation. Using DFA, it was previously shown that while exposure to an acute stressor did not alter the total amount of vigilance behaviour, it did change the temporal structure.

Although the DFA revealed novel changes in behaviour under stress, the observation procedure – focal observations lasting 3072 s – was very time-consuming. Here, the effect of using shorter observation lengths or less frequent sampling was determined using a new data set. DFA was applied to 73 sequences of vigilance behaviour in ISA Brown hens. Systematic reduction of the duration of observation yielded a more structured behavioural pattern, reflecting the expected greater autocorrelation in shorter sequences. On the other hand, decreasing the sampling frequency led to a more random structure, reflecting a poorer representation of the 'true' behavioural organization. It is concluded that when DFA is used to measure behavioural organization in stress assessment studies, the use of focal sampling and shorter observations is preferable to that of scan sampling and decreased resolution.

POSTER 7
Developing a computer vision system for the online quantification of the behaviour of laying hens in furnished cages

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The purpose of this study was to develop a more objective online image processing technique to quantify the behaviour of laying hens as opposed to the current human visual observation. The image processing system is based on the principle that the classification of behaviour can be translated to classification of time series of different postures of the hen.

The system consists of a camera that is mounted above the cage, to get a top-down view. The contour of the laying hen in each camera image is extracted using a model-based segmentation method. The parameters from this model are stored as a description of the hen's posture in that image. As a next step, the trajectories of the model parameters are approximated by a model function within a certain time window. The parameters from the model function are then used to classify the hen's behaviour as, for example, egg laying, wing stretching, pecking.

A first implementation of the system was tested on a sequence of 640 images containing three different types of behaviour (standing, sitting and pecking). The set of parameters for each image was plotted by using a multi-dimensional scaling algorithm, showing three clear clusters corresponding to each behaviour class.

POSTER 8
How do laying hens employ their whole day?

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A better way to find directly the welfare-based parameters needed for the design of animal environments is to start from the 'environmental' demands of the animals themselves, expressed by their own activities. The demands can be transferred directly into design requirements. In this work the intensity and sequence of the behaviours of the hens were analysed in order to obtain an overview of the logistic structure of the hen society. Twenty ISA Brown breed laying hens, 18 weeks old, non-beak-trimmed, and commercial hatchery raised, were acclimatized for 10 weeks in a pen at 19±2°C room temperature with a rhythm of 9 h light and 15 h dark. Commercial feed and water was provided *ad libitum* throughout the experimental period. The behavioural data were recorded continuously for 10 days. The results of five hens for 5 days were selected for the analysis. Observer 4.1 (behaviour-recording software) was used to analyse the videotapes. Hens spent more than half of the time resting (27.71%), nesting (14.75%) and perching (13.56%). Hens were least active at night and most active in the late forenoon except for the preening behaviour, which was distributed throughout the day and night. More than 80% of the feeding sessions were under 3 min in length. Hens performed the feeding sessions throughout the day and night. However, the occurrence of the feeding sessions was high in the morning and in the late afternoon.

Poster 9
*Aggressive activity in red jungle fowl (*Gallus gallus*) and White Leghorn layers after re-grouping*

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Very little is known about how social behaviour characteristics have been affected by intensive selection processes in fowl. This study aimed to clarify selection effects on aggressive responses to re-grouping by comparing high-producing White Leghorns with red jungle fowl. The experiment consisted of two identical 3-week-long replicates, in which different individuals were used. Both replicates were preceded by a 21-day group isolation period, when birds were kept in four groups per breed each consisting of two cockerels and two hens. At the start, the ages of the birds in the replicates were 19 and 24 weeks old, respectively. Altogether 16 new single-sex groups of three birds from each breed per replicate were formed by mixing unfamiliar individuals from different isolation groups. Aggressive behaviours were recorded for 75 min, starting 0, 5, 24 and 48 h after re-grouping. Aggressiveness changed significantly over time in Leghorns but not in jungle fowl. Aggressive behaviours were significantly more frequent in Leghorns immediately after re-grouping, dropping temporarily at 5 h, maybe due to exhaustion. The frequency of aggressive behaviours returned to its initial level after 24 h in the Leghorn groups. It is suggested that this specific pattern of the dynamics of aggressive activity in Leghorns might be a general indication of a poorer social learning capacity with a weaker ability to cope with group disruptions compared to jungle fowl. At 48 h, the level of aggressiveness was the same in both breeds. A higher and prolonged aggression towards strangers might indicate an increased susceptibility to social stress in Leghorns when encountering changes in group structures.

POSTER 10
Use of vibration sensors in egg production and behaviour study in laying hens

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The influence of beak trimming and number of hens per cage on the welfare of laying hens allocated to enriched cages was investigated.

Two experimental air-conditioned and heated flocks were used to ensure temperatures within the range of 18–24°C. In each flock 12 enriched cages (Zucami M.E.C.) were housed in three-tiered batteries (8 × 3) each holding ISA Brown laying hens. Hens were divided into four treatment groups: groups of nine and ten per cage, and groups with and without beak trimming.

To detect poultry stress and restlessness in each cage, one vibration sensor (consisting of a level of acceleration detector VS-2, with shot level adjusted to 1.2 g and start of relay 24 Vdc and connected to one automaton Siemens, Simatic S7-200 connected to a computer) was installed, to detect movements of the laying hens.

Egg production and movement between 19 and 31 weeks of age were monitored. The percentage of eggs laid was the same in the four treatments and in the three tiers. In the highest tier, higher vibration ($P<0.05$) levels were detected than in the other two. Average impulses per day were: for the bottom level 93.9 (±40.01), second level 96.8 (±40.97) and third level 241.8 (±191.59). However, there were no differences between cages with and without beak trimming (155.8 versus 132.6) at these vibration levels.

POSTER 11
Measurement of nest-use time in laying hens, using occupation sensors

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The use of nests by ISA Brown laying hens housed in 24 enriched cages (Zucami M.E.C.) was studied in three-tier batteries (8 × 3). Birds were divided into four treatment groups: groups of nine and ten per cage and groups with and without beak trimming. One photocell pnp with reflection in mirror, feed to 24 V ca, and detection distance 4 m, with LED emission of red polarized light and connected to an automaton (Siemens, Simatic S7-200) connected to a computer, was installed in each nest to detect level of occupation. Every day all eggs were collected by hand and the percentage of eggs laid in the nests calculated over the period 19–31 weeks of age. The use of the nestboxes was high in all groups (higher than 69%).

The percentage of eggs laid in nests was the same in groups of nine and ten per cage, and higher in beak-trimmed hens ($P<0.05$) and in second tier ($P<0.05$).

Occupation time of the nest was highest in the second tier (379.3 ± 51.2 min/day) ($P<0.05$) than in the other two: first tier: 214.3 ± 53.7 min/day and third tier: 282.3 ± 54.8 min/day. However, there were no significant differences between beak-trimmed and non-beak-trimmed hens in nest occupancy times.

POSTER 12
Preference for Astroturf over conventional wire as a dustbathing substrate in furnished cages

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From 2012 all conventional battery cages for laying hens will be banned under European Directive 1999/74/EC. Furnished cages, which include a perch, nest area and a pecking and scratching area, will not be banned and have certain welfare, hygiene and practical advantages over other systems of egg production. However, even when a pecking and scratching area is provided in a cage, most dustbathing occurs on the wire floor as sham dustbathing (Lindberg and Nicol, 1997).

The aim of this study was to investigate whether laying hens in furnished cages would show a preference for dustbathing on a covered wire floor rather than on conventional bare wire flooring.

Eight groups of ten birds were housed in pairs of adjoining furnished cages. All birds were leg ringed for identification. Each pair of cages consisted of one cage containing Astroturf on the cage floor and one cage with a conventional wire floor, joined with a pophole through which birds had free access. The Astroturf was shorter than that found in the nestboxes and was perforated to allow droppings to pass through. Following a period of acclimatization, scan samples were carried out at 5-min intervals, between 1130 hours and 1600 hours, to identify the number of birds dustbathing on each flooring type. This was repeated on ten days.

Analysis using the binomial sign test showed a strongly significant preference for dustbathing on the Astroturf flooring ($P<0.01$), which was apparent in all cages.

REFERENCE

Lindberg, A.C. and Nicol, C.J. (1997) Dustbathing in modified cages: is sham dustbathing an adequate substitute? *Applied Animal Behaviour Science* 55, 113–128.

POSTER 13
Comparison of artificial turf and a wire mesh floor in nestboxes of enriched cages

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Directive 1999/74/EC stipulates, amongst other things, that cages for laying hens should be equipped with a nest, and moreover, the floor should not consist of wire mesh.

Little is known about the quality of eggs laid on artificial turf in enriched cages on commercial poultry farms. This was the objective of this study.

The study comprised a total of 1640 Brown laying hens in 40 cages with an incorporated group nest, 20 of which were equipped with a wire mesh floor. The remainder used artificial turf as floor cover. Each manual egg collection contained some 1600 eggs (±40 per cage) and was repeated every 8 weeks. Egg quality was tested by candling.

The results of these measurements can be summarized as follows: nests with a wire mesh floor produced significantly more eggs fouled with egg yolk or egg white, more cracked eggs and more eggs with dust, than nests with artificial turf. Eggs fouled with feathers occurred more often in nests with artificial turf.

Another aspect of the study examined the position where the eggs were laid. One of the problems in cage systems is the prevalence of eggs laid outside the nest. The percentage of floor eggs was significantly lower in nests with artificial turf than in nests with a wire mesh floor. Consequently, nests with artificial turf are more attractive to the hens than nests with a wire mesh floor.

POSTER 14
The pre-laying behaviour of laying hens on different nesting materials

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The objective of this study was to investigate the pre-laying behaviour on different nesting materials presented simultaneously.

One hour of behaviour before laying was analysed from video-recordings for 21 individual laying hens housed in a furnished cage. This cage was modified so that each hen had free access to three nestboxes provided with either coated wire mesh, peat or artificial turf.

Significantly more time was spent in nestboxes with peat ($\bar{x}$ = 23 min) and artificial turf ($\bar{x}$ = 15 min) than wire mesh ($\bar{x}$ = 3 min). Hens that chose to lay their eggs on peat spent more time in the oviposition nestbox ($\bar{x}$ = 46 min) than hens that chose to lay on artificial turf ($\bar{x}$ = 29 min). Out of the 14 defined behaviours analysed, type of nesting material had an effect on pecking. Frequency of pecking on peat was much lower than on artificial turf and wire mesh.

Behaviour scored as pecking for a large part included nest-building activities. Hence, it is concluded that hens perform more nest-building activities in nestboxes with peat versus coated wire mesh and artificial turf. We also tentatively conclude that hens laying on peat show more settled pre-laying behaviour (and nest-building activities) than those laying on artificial turf in the oviposition nestbox.

POSTER 15
Behaviour of pen-housed hens in relation to floor space allowance

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Under Council Directive 1999/74/EC, minimum space allowances ('usable areas') per laying hen range from 550 cm^2 in unenriched cages (from 1 January 2003) to 1111 cm^2 in alternative housing systems constructed since 1 January 2002. The outdoor allowance per free-range hen is 4000 cm^2. In reports on the welfare of laying hens by both the EC Scientific Veterinary Committee (1996) and the Farm Animal Welfare Council (1997), there is recognition that knowledge of hens' space requirements is inadequate. The present experiment studied expression of behaviour, including spacing, in five groups of six and one group of five ISA Brown hens aged 21–36 weeks in six test pens providing 600, 2400, 4800, 7200, 9600 and 12,000 cm^2 floor area per hen. Home pens provided 2400 cm^2 per hen. In similar work by Keeling (*Applied Animal Behaviour Science* 39, 131–140, 1994), the maximum area tested was 5630 cm^2. The main aim here was to identify a hypothetical point at which mutual repulsion equals mutual attraction (i.e. a 'bent stick' response). Treatments were applied to groups in different sequences according to a Latin square arrangement, daytime tests lasted 2 h and had no feeder or drinker present, overnight tests were done with 2400, 7200 and 12,000 cm^2 per hen and had a feeder and drinker present. Groups were video-recorded from above during testing to allow repeated measurements of spacing and behaviour. In the daytime tests, the relationship between mean (back to back) distance to nearest neighbour and floor space allowance was asymptotic, rather than a 'bent stick'. The steepest part of the response was between 600 and 4800 cm^2 per hen. With 600 cm^2 per hen, the hens walked less, ground pecked less, preened more and were stationary more than with greater space allowances. Changes in behaviour were greatest between 600 and 2400 cm^2 per hen and there was no significant change above 7200 cm^2 per hen. Spacing behaviour responses at night were the same as by day. It is concluded that any space allowance of less than about 5000 cm^2 per hen imposes at least some constraint on free expression of behaviour.

POSTER 16
Effects of opaque and transparent vertical cover on the distribution of hens in an outdoor arena

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In free-range systems, only a small proportion of the flock is seen outside at any one time (Grigor, 1993), with some birds rarely leaving the house. Providing range areas that are attractive to hens and more appropriate to their needs may encourage them to make greater use of the space provided. One solution may be to furnish range areas with suitable types of cover. However, the effects of providing cover have been shown to vary between species (Elton, 1939). This experiment investigated the effect of providing opaque vertical cover, transparent vertical cover, or no cover, on the distribution of hens in an outdoor arena.

Forty-eight hens were released in groups of four in the centre of an outdoor arena. The arena was divided into three sectors, radiating out from the central release point. Each sector contained one of three treatments that were tested in a balanced design: wire fence covered with black fabric (BF); wire fence (WF); no cover (NC). Time spent within each sector of the arena was recorded by scan sampling every 30 s during the 40-min test period.

On leaving the central release circle, hens were significantly more likely to enter the sector containing the BF cover (BF=64.2%; WF=24.3%; NC=1.5%; χ^2=128, df=2, P<0.001), and spent significantly more time in the sector containing BF cover (BF=66.2%; WF=19.1%; NC=10.7%; pooled SEM=6.2%, P<0.001). Results indicate that hens do seek cover in outdoor environments. Opaque cover was most attractive to hens despite the potential restriction to their field of view.

REFERENCES

Elton, C. (1939) On the nature of cover. *Journal of Wildlife Management* 3, 332–338.

Grigor, P.N. (1993) Use of space by laying hens: social and environmental implications for free-range systems. PhD thesis. University of Edinburgh.

POSTER 17
Carcass condemnations of laying hens not affected by low feed energy or protein content

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In Finland, carcass condemnations of layer hens increased from 5.8% to 24.0% between 1996 and 1999. One of the main reasons for condemnation was reported to be cachexy. The effects of different feed energy and protein contents on hens' live and carcass weights were therefore studied in two experiments.

In Experiment 1, dietary treatments during the laying period (18–70 weeks) were based on feed energy content (11.3–11.0 or 9.8–9.5 MJ/kg), and in Experiment 2 on feed energy content (11.4–11.1, 10.6–10.3 or 9.8–9.5 MJ/kg) and the feed protein:energy ratio (13 or 15).

In both experiments, the hens compensated for a low feed energy content by increasing their feed intake. At the end of Experiment 1, feed energy content had no effect on live or carcass weight. In Experiment 2, there was a significant interaction in the live and carcass weights of hens between feed energy content and the feed protein:energy ratio ($P<0.01$): at a high feed protein:energy ratio, weights decreased with a decrease in feed energy content, but at a low feed protein:energy ratio, feed energy content had no significant effect on weights. In both experiments, there were only a few condemned carcasses (7.6% and 6.3%). The nutritional state was good in 90% of the condemned hens. It is concluded that even when feed energy and protein contents do not meet the recommended levels, hens are able to maintain a normal live weight by increasing their feed intake.

Poster 18
*The effect of light programmes on red mite (*Dermanyssus gallinae*) in battery cage housing*

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Between 1996 and 1999 research on the use of light programmes to enhance eggshell quality in laying hens was done during three laying cycles.

During the last cycle, the 'Reading' programme [24(15minL:45minD)] and the Biomittent programme [16(15minL:45minD):8D] were compared. The study was done in two separate houses, each with two compartments. In each compartment 3360 hens were held in battery cages.

In two compartments (one in each house) the 'Reading' programme was used, and in the other two the Biomittent programme was used.

During the laying cycle the houses were infested with red mites (*Dermanyssus gallinae*).

In this study an interesting side-effect of the light programmes was noticed. In the two compartments where the Biomittent programme was tested, numerous mites were found dead on the manure belts after decontamination of the house at the end of the cycle. This was in contrast to the compartments with the Reading programme, where almost no mites were found. From this it might be concluded that the Reading programme somehow helps to control the population of red mites. A possible explanation is the alternation of light and dark, and the absence of a night in the 'Reading' programme. The lack thereof inhibits the mites from feeding on the hens, because they only come out during long periods of darkness.

This programme was used in several commercial farms with success, but since the implementation of Directive 99/74/EC, which stipulates that hens should have a night of 8 h, intermittent light programmes are forbidden.

POSTER 19
A radiographic and physiological appraisal of keel bone fractures in laying hens reared with perches

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Bone fracture, mainly in the furculum and keel, is a potential welfare cost of aviary and perchery systems.

Sixty-six Lohmann Brown layers, divided into four groups, were reared in floor pens (3.2 × 2.6 m). Three L-shaped wooden perches, positioned in one corner of the pen, were fixed to the floor at heights of 20, 30 and 60 cm (in total 7.2 m of perches). The angles between the low and medium perch and between the medium perch and the high one were 18.4° and 45°, respectively.

At 64 weeks of age, birds were killed by an overdose of barbiturate. They were handled with care to avoid skeletal damage. All carcasses were radiographed. Keel and humeral bone density was measured and the presence of new fracture, deformation and fracture callus was recorded. Samples of keel bones and proximal tarsometatarsus were subjected to qualitative assessment and histomorphometry. No fractures were observed in wing, leg or furculum bones, but 74% of the carcasses showed evidence of keel bone fracture. There was no significant difference in keel or humeral density, or in tarsometatarsal bone volumes, between the fractured and non-fractured groups.

These results indicated that fractured and non-fractured groups were similarly osteoporotic.

Keel fracture in laying hens housed with perches is therefore likely to be related to the presence or absence of insult rather than inter-individual differences in the skeleton's susceptibility to fracture.

This has important implications for housing system design.

POSTER 20
The performance and behaviour of non-beak-trimmed hens on a farm producing organic eggs

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On an organic farm in Norfolk, three houses of a similar size and construction contained 3000 laying hens per house, each flock consisting of a different commercial breed, all reared by the same firm but on different farms. None were beak-trimmed. The nutrition was the same in all houses (i.e. a commercially available organic feed, in crumb form). The stocking density was 6 hens/m^2. Veterinarians and the RSPCA were informed of the progress of the flocks.

Behaviour and performance of the hens differed markedly:

House 1 / Breed A

- The flock was depopulated early (when 67 weeks old), for welfare reasons.
- Feather pecking was extremely severe, leading quickly to 'bald' hens and then cannibalism.
- Feed intake was very high (144 g/hen/day).
- Hen-house egg production was depressed (245 eggs/HH).
- Mortality was very high (16.5%).
- Egg quality was poor (pale-shelled eggs, 12.7% seconds).
- Financial margin over feed cost: 78% lower than Breed C.

House 2 / Breed B

- The flock was depopulated early (when 65 weeks old) for welfare reasons.
- Well-feathered hens started cannibalizing at an early age and then feather pecked.
- In an effort to stem cannibalism, they were beak-trimmed when 29 weeks old (with veterinary approval).
- Beak trimming had no adverse effects on their performance.
- Cannibalism quickly resumed, leading to high mortality (14.2%).
- Hen-house egg production was depressed (240 eggs/HH).

- Financial margin over feed cost: 61% lower than Breed C.

House 3 / Breed C

- Performance and welfare (feathering and cannibalism) were exemplary with no problems whatsoever.
- To 72 weeks.
- 306 eggs/HH: 128 g/hen/day feed consumption: 4.8% mortality.
- Good financial margin.

This farm-scale 'trial' showed that the performance and behaviour of non-beak-trimmed hens could be unpredictable. Beak-trimming Breed B when 29 weeks old appeared not to have been stressful. Where the hens' behaviour was adversely affected, financial margins were markedly reduced. Feather-pecked hens were unable to continue to lay eggs whilst trying to re-grow feathers. The hens showed only a short-term interest in 'toys'. Feather loss was predominantly due to aggressive pecking and mortality from cannibalism, to vent pecking. Once started, these vices and peritonitis became unstoppable.

On this farm and on this occasion, there were clear differences in behaviour (feather pecking and cannibalism). However, because of the multi-factorial aetiology of these vices, further investigations are warranted in trying to establish whether there are indeed differences in the behaviour of non-beak-trimmed commercially available brown egg laying hybrids.

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