WELFARE ISSUES AND HOUSING FOR LAYING HENS: INTERNATIONAL DEVELOPMENTS AND PERSPECTIVES

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INTRODUCTION

There appears to be an increasingly widespread concern by people with the treatment of animals. Publications such as "Animal Machines" by Ruth Harrison (Harrison, 1964) and "Animal Liberation" by Peter Singer (Singer, 1975) have probably been important in stimulating this awareness, and this appears to be reflected in a shift in the ways in which the community in many countries is addressing its treatment of animals. While many attitudes to animal welfare may be based on little knowledge of the issue(s), or of animal management practices, these attitudes to animal welfare are, nonetheless, important for several reasons. On the one hand, attitudes to animal welfare can affect government, industry and community decisions on how animals are used and cared for. On the other, such attitudes may reflect cultural shifts in the way in which people see the place of animals in their homes and in the broader community.

Confinement housing of livestock such as those common in modern pig and poultry production appear to be at the forefront of these concerns raised by some in the community. On the basis of the popular press, one could be led to believe that the only welfare issues in relation to farm animal housing are stall (individual) housing of pigs, cage housing of laying hens, and overcrowding of meat chickens. These concerns in themselves raise a number of questions including the following: What is the best type of housing to provide and on what basis? Is outdoor housing better than indoor housing? What are the space allowance requirements of animals? What are the adverse consequences of housing pigs in stalls or laying hens in cages? What are the social requirements of animals? Assuming we can determine the requirements of different species for space and social contact, what other facilities should be provided? While extensive production farming systems are generally not considered to involve 'housing', extensive systems do impose restrictions on animals, albeit with considerable freedom, and there are different issues raised including frequency of inspections and opportunity for intervention, climatic conditions and natural disasters. Nevertheless, the main focus of welfare concerns has been on intensive confinement systems.

One of the reasons that housing of farm animals changed markedly post-second world war was because consumers and governments in western societies wanted cheap and safe food (Hodges, 2000). Science and the livestock industries responded and, consequently through more industrialized housing and production methods, have increased productivity, improved the quality of food and lowered the cost of food. Furthermore, these changes in animal housing and production methods have reduced or eliminated a number of welfare problems such as predation, thermal stress, some infectious diseases and nutritional stress. However, these changes have exacerbated or created other welfare problems such as overcrowding, social restriction and lameness, some of which will be considered in this review.

In a broad international examination of livestock production systems, one of the overwhelming impressions is the diversity. Not only is there variation between countries in the mix of housing systems but there is also variation between countries in the legislated or voluntary welfare standards for housing livestock. Furthermore, there is both between and within country diversity in attitudes to animal welfare. On top of this, there is considerable variation within science in both methodologies used to study animal welfare and the interpretation of these methodologies in terms of animal welfare implications. This review will examine the welfare of laying hens by examining international practices in housing laying hens, public attitudes to animal welfare, legislated or voluntary welfare standards for housing laying hens, and the scientific literature and its interpretation on the effects of housing and husbandry practices on laying hens.

This review is divided into four sections. In the first, we briefly describe the global status of egg production, the prevalence of different types of housing systems in use and hen welfare standards around the world. In the second section we consider research published on community and consumer perspectives regarding animal welfare and specifically the welfare of laying hens. In the third section, we discuss the perspectives of the scientific community, and how different approaches to defining and investigating animal welfare are used in scientific studies. In the fourth section we review the major key issues concerning the welfare of hens; we have attempted to integrate results from studies that use the different approaches.

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PART 1: OVERVIEW OF INTERNATIONAL EGG PRODUCTION, HEN HOUSING AND ANIMAL WELFARE STANDARDS

Global Egg Production

The last few decades have seen major changes in egg production worldwide. From 1990 until 2005 hen egg production increased 68% from 35,232 to 59, 233 (1,000 t) with the majority occurring in developing countries where production increased 146% compared to 1% in developed countries (from FAO data base as cited in Windhorst, 2006). This resulted in an increase in the global market share of egg production in developing countries from 46 % to 68% (Windhorst, 2006). Currently, China leads the world in egg production, followed by the United States, Japan, India, Russia, Mexico and Brazil (van der Sluis, 2008). Within the European Union (25), Spain, France, Germany, Italy, the Netherlands, UK and Poland account for approximately 73% of the European market share (IEC, 2008). Trade in shell eggs and liquid egg products is generally low and restricted to comparatively small regions because of costs of transport over long distances, although trade in processed egg powder is increasing and expected to continue (van Horne and Achterbosch, 2008). The main exporters of eggs are the Netherlands, Spain, China, Belgium, and the USA. Self-sufficiency rates in egg production vary considerably across Europe; for example the self-sufficiency rates for Switzerland, Sweden, Germany and Denmark in 2007 were 45, 85, 68 and 71%, respectively, whereas the Netherlands and Spain produced 306 and 114% of their requirements in that same year (IEC, 2008). Australia, Canada, New Zealand and the USA all had self-sufficiency rates of at least 100% in 2007 (IEC, 2008). Windhorst (2006) predicts that spatial patterns of production and trade flow will continue to change rapidly in the next few years, and that outbreaks of Avian Influenza, higher feed costs because of bio-fuels, and political decisions regarding the housing and welfare of laying hens will affect these changes.

Hen Housing Systems

A variety of different systems can be used to house laying hens. Various types of systems as well as specific features of systems have been the focus of research investigating effects of housing of the welfare of hens. Descriptions of various systems have been given in detail in previous reports (EFSA, 2005; Blokhuis *et al.*, 2007). Similar terms and definitions have been used for this review.

Cage systems are considered to be those that are operated from the outside and that stockpeople do not enter. Non-cage systems are generally large enclosures that stockpeople enter in order to inspect and service the birds.

Conventional cages are those constructed mainly of wire mesh with sloping wire mesh floors. They are equipped to facilitate feeding, drinking, egg collection, manure management and stocking and removal of birds. Some models may include abrasive strips for claw shortening. Divisions between adjacent cages may be wire mesh or solid. The number of hens housed in a conventional cage can vary with size of the cage and space allowance provided, but generally ranges from 3 to 7 birds.

The terms *furnished cage* and *modified cage* are used in this review to describe systems in which additional equipment is provided within wire mesh cages that facilitate opportunities for birds to perform a greater variety of behaviour patterns. This equipment may include perches, nest boxes, dust baths, an area of litter or a section of artificial turf in addition to the equipment provided in conventional cages. The term *modified cage* often refers to a conventional cage that has been retrofitted with some or all of this equipment. The term *furnished cage* usually refers to cage models that have been specifically designed and manufactured to include some or all of this equipment. A variety of furnished cages are commercially available and can accommodate different group sizes of birds. Small furnished cages have been considered to be those that are intended to house approximately 10 -12 birds, medium furnished cages house approximately 15- 30 birds and large furnished cages can accommodate upwards of 60 birds (EFSA, 2005). The term *enriched cage* has been used in some legislation to refer to a cage that includes a nest(s), perch(es), litter and claw shortening device(s) (EC Council Directive, 1999/74/EC), although the term *furnished cage* is considered to be more accurate because it factually describes the equipment provided rather than some intended function of it (EFSA, 2005).

Non-cage housing systems include a wide variety of layouts and designs that accommodate various large group sizes and stocking densities of birds. They may be completely indoors or provide birds with access to the outdoors. Non-cage systems generally include nest boxes and sections of raised perforated platforms and may or may not include perches. Many non-cage systems include a section of floor that is covered with litter, although provision of litter can vary with country in which these systems are operated. Systems in the EU require provision of litter (EC Council Directive, 1999/74/EC), whereas many non-cage systems in North America are operated completely on slatted floors. Single-level (single-tier) systems are those in which birds only have access to one level of flooring although different sections of the floor may be at different heights (slatted areas or platforms). Multi-level systems (aviaries) provide birds with access to more than one level of perforated (slatted) floors. In aviaries, feeders, drinkers, perches and nest boxes may be located at different or on multiple levels. Some non-cage systems provide birds with access to a covered outdoor area that is connected to the hen house. *Free-range* systems are those that provide hens with access to an uncovered outdoor area that may provide some vegetation cover.

The majority of commercial laying hens in the world are kept in confined housing systems that utilize mechanical ventilation, automated feeding and egg collection and artificial lighting programs (van Horne and Achterbosch, 2008). Although the majority of these hens are also kept in conventional cages, there is some variation in housing systems used in different parts of the world, with an increasing number of hens in the European Union kept in non-cage systems as the deadline for EU Directive (1999/74/EC) approaches (see next section). Figure 1 shows the percentages of hens kept in cages, barn (non-cage systems) and free-range systems for some selected countries in the world (IEC, 2008). Cage systems presented in the graphs include both conventional and furnished designs, although outside of Europe, few furnished cages are in use commercially. In Sweden, all cages are furnished, since the majority of conventional cages were exchanged for either non-cage or furnished cages by 2004 (Fossum *et al.*, 2009). Outside of the EU, only Australia and New Zealand have a significant proportion of non-cage systems. The non-cage and free-range systems reported for China and India may represent non-commercial backyard production (van Horne and Achterbosch, 2008). The significant changes between 2006 and 2007 in China and India may represent rapid regional changes in production because of outbreaks of Avian Influenza.

International Standards, Codes and Legislation

To date, poultry welfare has been given more legislative attention in the Europe than in most other regions of the world (van Horne and Achterbosch, 2008). The European Union Directive (1999/74/EC) established legislated minimum standards for the housing of laying hens in its member countries. From January 2003, all hens housed in cages were to be provided a minimum of 550 cm^2 and a claw shortener, and no new conventional cages were allowed to be brought into service. By January 2012, all laying hens in member states are to be housed in either enriched (furnished) cages or non-cage systems. In addition to providing 750 cm^2 of space per hen in floor space with a minimum cage height of 45 cm, cages must be furnished with a perch, nest box, claw shortener and litter. By January 2007, all non-cage systems were to provide a minimum stocking density of 9 hens per m^2 of usable area, nest boxes, at least one third of floor area covered in litter and 15 cm of linear perch space per hen.

Individual member countries are allowed to have stricter laws and there are substantial regional differences across the EU. For example, the Dutch parliament voted to prohibit enriched cages, following the German example of allowing only large colony cages (IEC, 2008). Beak trimming is also regulated in the EU with regard to staff training and age at trim, but some countries such as Sweden, Norway and Finland, prohibit the practice altogether. Other EU countries such as France, Italy, Spain, Poland and Hungary have only the basic requirements of the EU Directive (van Horne and Achterbosch, 2008). Switzerland, which is not a member of the EU, has prohibited the use of cages for laying hens since 1992 (Appleby, 2003).

Outside of Europe, only Australia, New Zealand, the United States and Canada have developed legislated or voluntary standards for the welfare of laying hens. In Australia, animal welfare legislation is a state responsibility that is generally limited to protection of animals from cruelty and in some States, provisions for duty of care (Barnett and Hemsworth, 2009). In addition to legislation, there are a series of Model

Codes of Practice developed by and agreed to for national adoption by the Primary Industries Standing Committee (PISC). The provisions in Codes of Practice generally rely on voluntary compliance, although there are examples where entire codes e.g. South Australia (Prevention of Cruelty to Animals Act, 1985) or some code provisions are incorporated into legislation, e.g. space allowance for hens in cages in Victoria, Australia (Prevention of Cruelty to Animals (Domestic Fowl) Regulations, 2006). However, in Australia, these are exceptions as most States tend to use a lack of adherence to provisions in the codes of practice as supporting evidence when prosecuting cruelty. In August 2000 ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand; now PIMC (Primary Industries Ministerial Council)), which provides a discussion forum for State agriculture ministers, agreed to implement a number of changes in relation to the egg industry. These included i) cage systems that did not meet the 1995 standards (450 cm^2/hen, 10 cm feeder space, 40 cm cage height and fully opening doors) were to be replaced on or before 1 January 2008 unless they were modified to meet the new standards. ii) cages purchased from 1 January 2001 are to provide a floor space of 550 cm^2/hen, 12 cm feeder space and 40 cm cage height. iii) cages that meet the 1995 standards and purchased prior to 2001 are to have an economic life of 20 years from the date of purchase, although any replacement cages must meet the contemporary standards current at the time. Thus, in Australia it was agreed that the States would enact legislation to comply with the ARMCANZ agreement that had the major effect of increasing the space allowance of hens in cages to 550 cm^2/hen.

In New Zealand, the Codes of Animal Welfare and Codes of Recommendations and Minimum Standards provide the framework for animal welfare regulations under the Animal Welfare Act 1999. Although the recommended best practices in the codes are not legally binding, minimum standards are; failing to meet a minimum standard can support a prosecution under the Act (http://www.biosecurity.govt.nz/regs/animal-welfare/stds). The Animal Welfare (Layer Hen) Code was released in 2005 and details minimum standards for all hen production systems. The NZ code has similar provisions for space allowance in cages to Australia of 550 cm^2, although phase in time is longer. (http://www.biosecurity.govt.nz/files/animal-welfare/codes/layer-hens/layer-hens-code-of-welfare.pdf). All cages must meet the 550 cm^2/hen space requirement by 2014 as must cages purchased after 2005. The New Zealand code is currently under review (2009) and a final decision on whether conventional cages should continue, be modified or phased out will be made subsequent to the review.

In the USA, there are a few federal laws related to livestock transport, handling and slaughter, although poultry are generally excluded (Mench, 2008). Individual states, however, do have the power to regulate housing, care and handling of animals, although state law cannot supersede federal law. In the past few years several state initiatives have passed, consequently prohibiting the use of gestation stalls for sows in Florida in 2002, and gestation stalls for sows and crates for veal calves in Arizona in 2004. In 2008, a voter referendum in the state of California (Standards for Confining Animals, Proposition 2,) was passed that will prohibit the confinement of pregnant sows, veal calves and hens in enclosures that do not allow them to stand up, lie down, turn around and fully extend their limbs, effective 1 January 2015 (http://www.sos.ca.gov). Prior to these recent changes in state legislation, food retailers were the primary drivers of animal welfare standards in the USA (Mench, 2003). In response to this, the United Egg Producers industry group (UEP) developed a set of guidelines for caged laying hens that increased the minimum space allowance from 310-348 cm^2 to 432-561 cm^2 per hen, and set standards for such things as air quality and beak trimming (Bell *et al.*, 2004). In 2006, the UEP prohibited feed withdrawal as a means of inducing moult, and in 2008 set standards for non-cage egg production system (Mench, 2008). In order to ensure compliance with these standards, the UEP established a third-party auditing program that allows producers to display their certification logo. In 2009, it was reported that approximately 80% of producers in the United States egg industry was participating in the program (http://www.unitedegg.com/animal_care.aspx).

Animal welfare legislation for farm animals in Canada is generally limited to federal and provincial laws concerning cruelty, transport, slaughter and sales yards (http://www.inspection.gc.ca/english/anima/trans/infrae.shtml). The Recommended Codes of Practice for the Care and Handling of Farmed Animals are voluntary codes consisting of recommended husbandry guidelines and as such are not intended to be standards, although they are referenced as acceptable standards of animal care by the

Animal Care Act in the province of Manitoba. The first Recommended Code of Practice for the Care and Handling of Poultry was developed in 1983 and revised in 1989. A more recent revision was published specifically for layer hens in 2003 (Recommended Code of Practice for the Care and Handling of Pullets, Layers and Spent Fowl). This code recommends minimum cage space allowances of 432 cm^2 for white egg layers and 483 cm^2 for brown egg layers, as well as providing recommendations for feed and water spaces, and age and management of birds for beak trimming, similar to those in the USA. In 2004, the Canadian Egg Marketing Agency (currently Egg Farmers of Canada) together with the provincial egg marketing boards introduced an animal care rating and inspection program based on the Codes of Practice that was coupled with their food safety program. As Canada currently has a supply management system overseen by the Egg Farmers of Canada and provincial boards, egg farms registered within the system are annually checked for compliance with the codes (http://www.canadaegg.ca).

Although some countries or states within countries in Africa, Asia and South America do have cruelty legislation or laws concerning animal welfare transport and slaughter (e.g., Brazil, India, South Korea, Taiwan and Uganda, for full listing see http://www.ll.georgetown.edu/guides/InternationalAnimalLaw.cfm), none have either legislation or voluntary standards concerning the housing of laying hens (da Cunha, 2007; van Horne and Achterbosch, 2008). Van Horne and Bondt (2005 as cited in van Horne and Achterbosch, 2008) reported that the majority of hens in India, Ukraine and Brazil are kept in cages with a space allowance of 350 to 400 cm^2. A National Plan for Poultry Safety and Animal Welfare is being developed in Brazil and animal welfare is now being discussed in the National Advisory Committee in the Japanese government (IEC, 2008).

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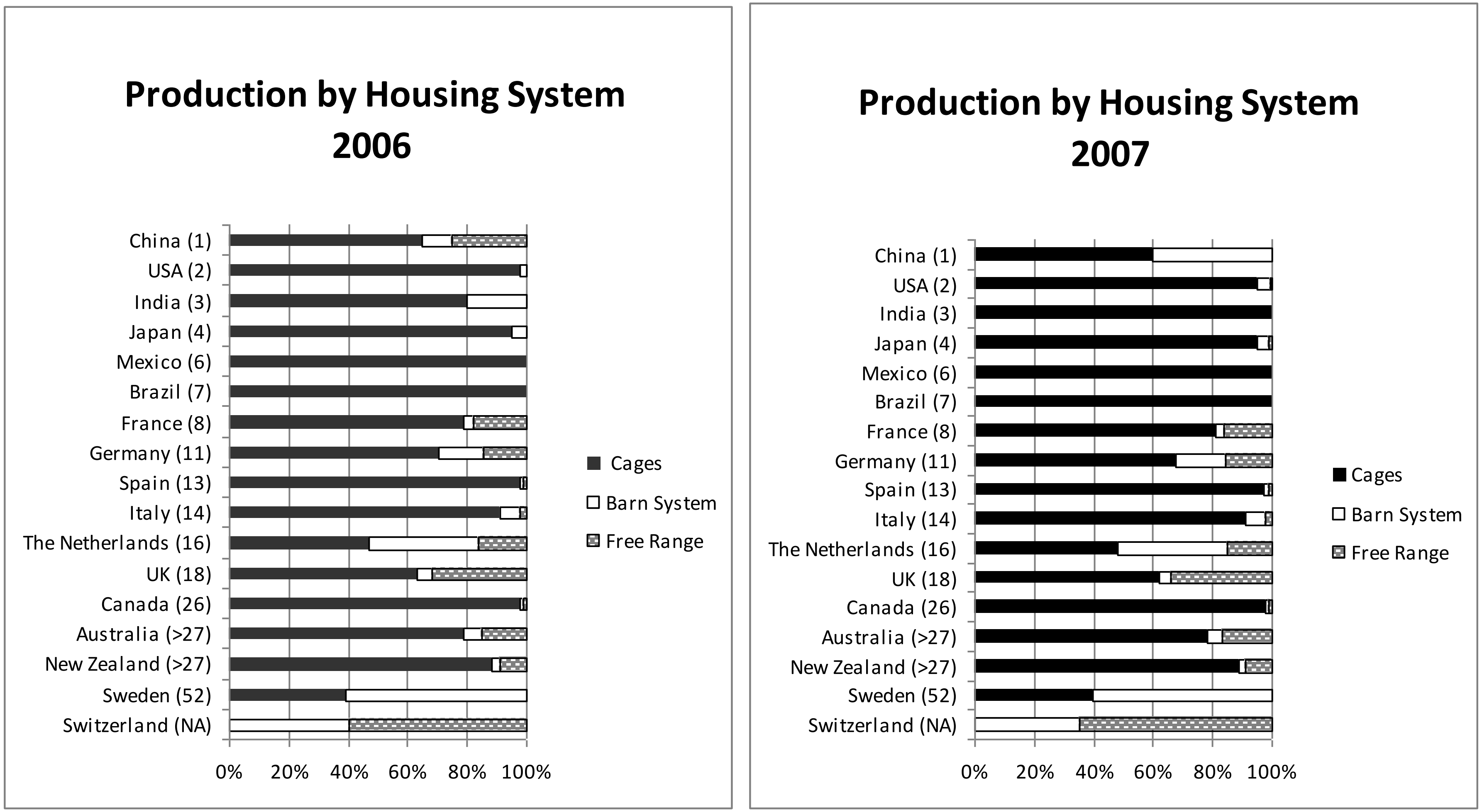

Figure 1. Percentage of eggs produced in different housing systems reported by member countries of the International Egg Commission for 2006 and 2007 (IEC, 2008). The global ranking for production of hen eggs as calculated by FAO for the year 2005 is given in parentheses.

PART 2: UNDERSTANDING ANIMAL WELFARE: COMMUNITY AND CONSUMER PERSPECTIVES

People’s attitudes to animal welfare have been studied in a variety of ways with the goal of using this information in the development of public policy for the treatment of farm animals (e.g. Bennett, 1997) and labeling of their products (e.g. Harper and Henson, 2001) as well as for determining marketing strategies for the sale of meat, dairy and poultry products (Harper and Makatouni, 2002; Vanhonacker *et al.*, 2007). Public opinion surveys and polls are often used simply to gauge people's views on farm animal welfare and how they differ over time or across regions (e.g. European Commission, 2005; 2007). Economic and marketing research generally investigates whether and how consumer's attitudes about animal welfare influence their perceptions about food attributes (Harper and Makatouni, 2002; Parrott, 2004), their stated willingness to pay for animal welfare improvement (Bennett, 1998) and their actual purchasing behaviour (Parrot, 2004). Sociological and psychological approaches generally aim to identify how demographic and experiential factors affect people's attitudes about animal welfare (Kendall *et al.*, 2006) and how people’s attitudes in turn, influence their behaviour (Coleman *et al.* 2005). Methods vary considerably and include descriptive and various multivariate analyses of quantitative data derived from surveys (e.g. Coleman *et al.*, 2005; Boogaard *et al.*, 2006; Vanhonacker *et al.*, 2007) and content analysis of qualitative data derived from focus groups and interviews (e.g. Harper and Makatouni, 2002; Lassen *et al.*, 2006). The majority of published literature on public and consumer attitudes comes from Europe where farm animal welfare legislation and consequent economic implications have made this a key issue. There is considerably less information about people’s attitudes toward farm animal welfare in other parts of the world.

Public opinion surveys do not often address the attitudes underlying concerns about the welfare of farm animals, let alone those specific to the egg industry, and for this review it is necessary to draw on surveys across all of the livestock industries. One must be cautious in extrapolating survey data from other industries, particularly the meat industries, to the egg industries as a major difference that is generally not considered is that laying hens are not killed to specifically provide a product. There are also differences in public perceptions and attitudes about the treatment of different species of farm animals (European Commission 2005; Maria, 2006) and specific industry practices such as cages for hens (Lusk *et al.*, 2007). It is also important to keep in mind that the validity of survey data depends on sampling techniques, what questions are asked in the surveys, how the questions are constructed and how the answers are scaled.

The importance of farm animal welfare and its relevance to consumer and community behaviour

In general, results of most recent public opinion surveys conducted in the United States, Australia and Europe indicate that when people are simply asked whether the welfare of farm animals is important to them, the majority of people say yes. A 2004 survey of nearly 2000 citizens in Ohio (USA) showed that 92% of respondents agreed that "it was important to [them] that animals on farms were well-cared for" (Rauch and Sharp, 2005) and 71% of 1061 respondents in Victoria (Australia) agreed that "farm animal welfare is an important consideration" (Coleman, 2008). In a survey of 1500 people conducted in Italy, Great Britain and Sweden 87%, 73%, and 85% of the respondents in those countries, respectively, indicated that farm animal welfare in general was important to them (Mayfield *et al.*, 2007), and of 3978 people surveyed in Spain 42% indicated a medium level of concern on animal welfare while 46.8 % reported high or very high concern (Maria, 2006). When over 28,000 people sampled from all of the EU Member Countries were ask to rate how important it is "that the welfare of farm animals is protected" on a scale from 1 (not at all important) to 10 (very important), the average rating was marginally under 7.8 (European Commission, 2007).

Few public opinion surveys gauge animal welfare against other societal concerns in order to determine their relative importance. A telephone survey across the United States involving 1019 respondents was conducted into individuals' preferences for farm animal welfare (Lusk *et al.*, 2007; Lusk and Norwood, 2008). The sample size was low considering the US population and there was only 16% response rate, but the authors suggested that respondents were representative of the wider population based on age, ethnicity, household size and income. Ninety-five percent of respondents agreed or strongly agreed that "it [was] important to [them] that animals on farms are well cared for". Each respondent was also asked to rank the relative importance of two issues (using a dichotomous choice method), with a total of seven issues surveyed across the sample. Farm animal welfare ranked the lowest (share of preference = 4%), while human poverty (24%) and the US health care system (23%) ranked the highest. Food safety (22%) and the environment (14%) both ranked above the financial well-being of farmers (8%) and food prices (5%). At the same time, over 60% of respondents indicated that the government should take a more active role in promoting farm animal welfare and over 70% indicated that they would vote in favor of a law that would require farmers to treat their animals more humanely (Lusk *et al.*, 2008). Based on results of these and other questions, the authors concluded that although American consumers believed human welfare issues to be more important than animal welfare issues, consumers also appear to desire progress on the animal welfare front (Norwood, *et al.* 2007).

A more formal statistical approach for quantifying the perceived importance of public policy issues is Contingent Valuation (CV), a survey-based economic technique used extensively in environmental economics to determine the value that people place on non-market resources or public goods (Smith, 2006). Measures of people's stated willingness to pay (wtp) is used to provide quantitative estimates, in dollar terms, of the relative value that people place on things such as clean air, fresh water or biodiversity, and although the technique is controversial, it has played a role in a number of policy debates (Cooper, 2006). Based on the results of a pilot study using a sample population of 137 students at University of California, Davis, Bennett and Larson (1996) suggested that contingent valuation could be used to determine preferences of society for animal welfare legislation. Bennett (1997) then applied CV to evaluate public support in Great Britain for legislation to phase out the use of cages in egg production in the European Union. The survey of 2000 people in the UK on farm animal welfare and food policy received 591 (30%) responses. Of these, 41% were very concerned about the possibility of farm animals being mistreated and a further 45% were somewhat concerned. Fifty eight percent said battery cages for laying hens were very unacceptable and a total of 76% were, to some extent, negative. Seventy nine percent supported legislation phasing out battery cages in the European

Union by 2005. Using a dichotomous choice method, respondents were asked whether they were willing to pay a specified amount (wtp) as an increase in egg prices or an increase in taxes to cover the cost of legislation. Twelve different combinations of wtp were randomly assigned to different respondents and the mean additional amount determined from the statistical analysis was 43p per dozen eggs (based on 1997 prices of £1.40 per dozen). Bennett did not look at the priorities of respondents although he later reported that wtp in that survey was correlated with concern about animal welfare (r=0.28) and satisfaction of knowing other people cannot consume cage eggs (r=0.31) but not with purchase of free range eggs (r=-0.09) (Bennett, 1998). He suggested that respondents considered legislation to be a different public 'good' than their personal choice as to whether they purchase caged eggs or not. In a later exploratory study using a sample of 119 undergraduate students (Bennett *et al.*, 2002) suggested that wtp was sensitive to the degree of moral imperative of an issue, because the respondents' stated wtp was greater for legislation related to export of live animals for slaughter than it was for cage egg legislation. However, the mean importance score for live animal export (7.0) only tended to be greater than that for battery cages (6.6, P<0.10) and 73% of respondents supported cage legislation while only 58% supported export legislation. Apart from Bennett's studies, no other researchers have used contingent valuation to address animal welfare policy.

Using simple survey techniques, a number of public opinion surveys have also have indicated that a majority of people say that they would be willing to pay more for animal products (Rauch and Sharp, 2005; Maria, 2006) and more specifically for eggs (European Commission, 2005) coming from alternative ('welfare-friendly') systems. However, stated willingness to pay for food produced in alternative systems often does not actually translate into actual purchasing behaviour (Harper and Henson, 2001). For example, Parrott (2004) reported that although over 50% of a sample of 354 British consumers listed 'Method of production' as one of the two most important factors they looked for when buying eggs, and 62% said that they always or sometimes purchased free-range eggs, 61% indicated that they never actually look for reassurance on egg packaging for how the hens had been treated. Parrott (2004) reported that at the time the survey was conducted 80% of actual egg sales came from cages. Maria (2006) reported a similar inconsistency in the reported willingness to pay of 3978 respondents and actual consumption of 'welfare friendly' products in

Spain. Mayfield *et al.* (2007) also reported that although 71%, 65% and 47% of the 1500 British, Swedish and Italian consumers surveyed said that they usually chose free range over caged eggs, the stated preference was not reflected in the national egg market statistics of any of those countries.

There are likely a number of reasons for the discrepancies between stated willingness to pay and actual purchasing behaviour on per capita consumption of ‘welfare friendly’ products. One is that people respond to surveys as ‘citizens’ and make purchases as ‘consumers’. Vanhonacker *et al.* (2007; 2008) refer to this as the duality of citizen-consumer attitudes. They argue that citizen-public attitudes about animal welfare encompass a broad concept about animals’ physical and emotional health, cognition and general welfare, whereas consumer attitudes encompass a number of different product attributes that determine their food choices. Traditional ethical and political theories make a distinction between the consumer and the citizen in that the consumer makes egocentric decisions while the citizen considers the consequences of their actions on the public domain (Korthals, 2001). Food purchasing behaviour, therefore, is influenced by a host of factors, only one of which is a social concern about animal welfare (Harper and Henson, 2001). Vanhonacker *et al.* (2007) argues that people tend to answer questionnaires as ‘citizens’ and in this role claim to pay more attention to animal welfare. In addition, the authors argue that since animal welfare is considered to be a moral and ethical issue, people tend to give what they believe are socially desirable answers on questionnaires. Lusk *et al.* (2007) found that while 95% of US respondents indicated concern for farm animal welfare, only 52% agreed with the statement that “the average American thinks that farm animal welfare is important”. The authors suggested that responses to this latter question indicated that respondents overstated their true concerns for animal welfare in the first question. However, this interpretation may oversimplify the psychology of human behaviour because responses to these types of questions depend on their behavioural relevance and the extent to which they are based on people’s experience and/or knowledge.

The behavioural outcomes that may be determined by people’s attitudes as citizens would include supporting animal rights groups, donating money to animal welfare organizations, or protesting publicly about some current issue relating to animal welfare. These behaviours have important implications for the egg industry because of the ways in which decision makers react to such community behaviours. Behaviour by regulators relate to enforcement of laws and regulations, revision of codes of practice and drafting of regulations. Regulators and politicians may frame legislation and respond publicly to welfare issues on the basis of both their own beliefs about animal welfare and their beliefs about community attitudes. Retailers may impose welfare standards on the supply chain on the basis of their perception of community attitudes no matter what legislation may dictate.

Coleman *et al.* (2005) interviewed over 1000 Australians at supermarkets and by telephone and found that 56% of respondents indicated that they had engaged in at least one activity in opposition to livestock farming such as signing petitions, donating money to a welfare organization or speaking to friends/acquaintances/family members about an issue (community behaviour). The interview also addressed a number of questions about people's attitudes to eating meat, farming practices and concerns for animals used in different ways by humans as well as their self-reported consumption of eggs and pork. The authors found that attitude variables accounted for more of the variation in community behaviour (22-23%) than for variation in self-reported (7 and 8%) or point of sale (11 and 11%) purchases for eggs and pork, respectively. These findings are in line with the idea that attitudes to animal welfare may be more likely to translate into community (citizen) behaviour than to purchasing (consumer) behaviour.

Another reason for the lack of consistency between stated willingness to pay and consumption may be due to the fact that many of the studies also do not address individual differences in people's attitudes. In other words, they do not measure the relevant social context variables and report averages rather than considering separate segments of society with alternative views. Vanhonacker *et al.* (2007) demonstrated the importance of considering different segments of society in their study of 459 Belgians. The authors used a number of constructs including perceived importance of product attributes in purchasing decisions (e.g. animal welfare, food safety, health, taste, quality, price), evaluative beliefs about current state of animal welfare in Flemish farming, consumption behaviour with regard to meat, subjective knowledge (how knowledgeable they thought they were) and objective knowledge (specific factual questions) regarding farming. Cluster analysis was used to determine segments of the sample with regard to attitudes and purchasing behaviour. Four segments were identified: two extremes comprising 13% of the people who were generally not concerned with farm animal welfare, had positive evaluations about farming and were not willing to pay extra at the one end, and another 11% who were highly concerned about animal welfare, had negative opinions about farming and were either vegetarian or highly committed and highly willing to pay for animal welfare at the other. Two other groups were intermediate, each tending to lean toward one of the extremes. Interestingly, people in the two extreme groups were the most knowledgeable about livestock production practices.

Surveys of consumers in Belgium (Verbeke and Viaene, 2000) and the Netherlands (Frewer *et al.* 2005) showed that when making purchasing decisions, animal welfare concerns were secondary to human health concerns, and treatment of farm animals ranked below the importance of other product attributes such as food safety, freshness, and taste. Similarly Coleman *et al.* (2005) found a general consensus among Australian respondents that quality, appearance, being Australian in origin and shelf life were the top four products attributes while humane treatment of animals ranked fifth for pork products, sixth for egg products and seventh for animal products in general. However, a number of studies also indicate that consumers around the world use animal welfare as an indicator of other product attributes such as food safety, healthiness (Harper and Henson, 2001; Harper and Makatouni, 2002), and quality (Maria, 2006; European Commission, 2007) or at least they believe that there is a link between good welfare and a safer, better tasting product (Norwood *et al.*, 2007). Consumers often confuse attributes of organic and free-range products (Harper and Makatouni, 2002) and many consumers think that free-range eggs taste better (Parrott, 2004; Skarstad *et al.*, 2007). Many consumers also admit that when purchasing eggs, milk or meat they do not think about the animal that produced the product (European Commission, 2005; Lassen *et al.*, 2006; Mayfield *et al.*,, 2007; Skarstad *et al.* 2007) and when making food purchases the consumers think of personal benefits rather than the animal (Skarstad *et al.* 2007). At the same time, 74% of European (European Commission, 2005) and 52% of American consumers (Norwood *et al.*, 2007) surveyed believe that their purchasing behaviour can have a positive impact on the welfare of farm animals.

From the research outlined above, several points can be made. First, attitudes to animal welfare do not appear to have much direct effect on egg purchasing behaviour. Second, such attitudes do appear to predict community behaviours that, in turn, may affect the way in which retailers, regulators and legislators impose welfare standards on the egg industry. More emphasis on consumers as citizens is needed in the monitoring of community attitudes to hen welfare.

How do citizens/consumers define animal welfare?

The interpretation of the concept of animal welfare can differ considerably among different stakeholder groups. Several quantitative and qualitative studies have attempted to determine different people's beliefs about what constitutes good animal welfare. For each of 72 individual aspects of farm animal welfare (e.g. availability of water, disease, exposure to daylight), Vanhonacker *et al.* (2008) determined the degree of importance to animal welfare and to what extent the aspect was considered to be problematic in current Flemish production practices for a sample of 459 non-farming citizens and 204 livestock producers in Flanders, Belgium. The individual aspects were assigned to 7 key dimensions: 1) housing and climate 2) transport and slaughter 3) feed and water 4) human-animal relationship 5) animal suffering and stress 6) animal health and 7) ability to engage in natural behaviour. There were a number of similarities between the sample groups in what was deemed important to animal welfare; aspects of feed and water, human animal relationships and animal health were considered to be the most important dimensions for both the citizens and the farmers. However, citizens perceived the ability to engage in natural behaviour as more important for animal welfare than did farmers and the highest level of discordance between evaluative beliefs of citizens and farmers were for aspects related to natural behaviour, pain, stress and the availability of space. Citizens generally viewed the current status of farm animal welfare as more negative than did farmers.

Several other studies also suggest that citizens/consumers consider the animal's ability to lead natural lives or exhibit normal behaviour as part of their concept of good animal welfare (Harper and Hensen, 2001). Frewer *et al.* (2005) sampled 1000 Dutch consumers about their attitudes to either pig or fish husbandry. Results from principal components analysis on data from both sample groups indicated that consumers think about animal welfare according to two broad categories; one related to the animals' health that included aspects of health, hygiene and skilled stockmanship and another that related to the animals' living conditions and included aspects of comfortable and natural living conditions and prevention of fear and stress. Similarly, reports of two qualitative studies based on focal group discussions and individual interviews in Norway (Skarstad *et al.*, 2007) and the Netherlands (Lassen *et al.*, 2006) indicated that consumers' definitions of animal welfare include the idea of animals "living as close to nature" as possible and "living a natural life", respectively. A public opinion survey in the United States indicated that providing ample food and water and treatment for injury and disease were the top ranked factors with regard to relative importance for animal welfare (Lusk *et al.*, 2007). The ability to exhibit normal behaviours and to exercise outdoors ranked next (but with considerably lower scores than the top two) and were more important than protection from other animals and provision of shelter at a comfortable temperature.

The notion of 'natural living' as a part of their concept of good animal welfare may be reflected in peoples' views of the welfare of different farm animal species and the perceived degree of confinement associated with those industries. For example, when Spanish respondents were asked to score the treatments of different species from zero (very bad) to 100 (excellent), ruminants and horses scored significantly higher than poultry, swine and fur animals, with broilers and laying hens viewed as having the poorest welfare of all livestock species (Maria, 2006). Consumers in Britain, Italy and Sweden believed welfare of laying hens to be the poorer than dairy cows, with that of pigs being intermediate (Mayfield *et al.* 2007). Results of a survey across countries in the European Union indicated that the majority of respondents had a negative view of laying hen welfare (58%) and a positive view of the welfare of dairy cows (68%), although there were significant regional differences in opinion among people in individual member states (European Commission, 2005).

Changing attitudes about farm animal welfare are often suggested to be a function of the degree of urbanization in society and a general lack of involvement with livestock farming (Appleby, 2003). Several studies have addressed related demographic and experiential factors that influence attitudes to farm animal welfare. Boogaard *et al.*, (2006) surveyed 1074 Dutch citizens and used factor analysis to identify factors associated with societal perceptions of farm animal welfare. Connection to agriculture significantly affected people's perceptions in that people without farm experience perceived famers' image and quality of life of farm animals to be less positive than did people with farm experience. From a sample of over 4000 Ohio residents, Kendall *et al.* (2006) found that childhood experience was most influential in that people who grew up in non-rural non-farm settings expressed greater concern for animal well-being than those who grew up in non-urban and farm settings regardless of their current residence. Appleby (2003) noted that countries in the European Union with a larger proportion of their population employed in agricultural labor were much slower to ratify the Council of Europe's 1976 Convention of the Protection of Animal Kept for Farming than were the more industrialized countries.

In reviewing the sociology of consumption, Kjaernes (2005) pointed out that individuals have very little direct exposure to livestock or livestock production and that this has implications for the relevance of animal welfare to the consumption of animal products. She argues that food consumption is largely based on habit and that these habits are the consequence of normative pressures that are embedded in the social environment. In particular, purchases are not the consequence of individual decisions at the point of sale but become incrementally established. Equally, the attitudes that underlie habitual behaviours may be based on erroneous knowledge or on vicariously learned beliefs based on observation of others. Kjaernes also recognises that "in some situations, routinized practices become explicit and contested, (and) there can be an intermittent break-up in the routines - an exception, or new and alternative, often ideologically justified, habit may be established" (p. 68). This suggests that if adequate information is available on public attitudes and the knowledge and beliefs that underpin these attitudes, then they may be an opportunity to influence them.

This begs the question: how much do consumers actually know about livestock farming practices and how does greater familiarity with farming practices influence their views? To ascertain consumer's level of knowledge, Parrot (2004) included questions in his survey of British consumers' attitudes about the welfare of hens in different systems. A large proportion of respondents said they had no idea how free range systems affected a hen's ability to roam (data not reported) and largely believed that hens in cages required more medication and were more prone to disease and fighting. Forty percent said they had no idea about the difference in health and behaviour between systems. More recently 57% of Europeans surveyed say that they know a little about the conditions under which animals are farmed in their country and 28% claimed to know nothing at all, with the level of self-reported knowledge being the highest in rural populations (European Commission, 2007). Increased exposure to farming practices may not necessarily lead to a more positive view and may be industry specific or differ with the individual. The majority of European respondents who visited a farm more than three times in their life were more negative about the welfare of laying hens compared to people who had not visited farms, whereas a higher frequency of farm visits seemed to be related to a more positive view of dairy farming (European Commission, 2005). As mentioned previously, segments of the population with the most extreme views about animal were those with the most subjective and objective knowledge about farming practices (Vanhonacker *et al.* 2005).

In summary, the attitude surveys generally indicate that the community shows a moderate to high level of concern about farm animal welfare issues. This applies to a greater or lesser extent to all of the Western countries surveyed. Furthermore there is a belief by consumers that buying behaviour will have an influence on retailers. However, it also appears that people's concern about farm animal welfare is multi-dimensional and the literature generally supports the notion of the citizen-consumer duality. While expressing broad concern for the treatment of farm animals, many people simply do not like to think about the animal when consuming animal products. Harper and Hensen (2001) suggest that European consumers "engage in voluntary ignorance in order to abrogate responsibility" (p. 5). For those consumers who prefer (or can afford) to purchase organic and animal welfare friendly products, their purchases reflect perceived benefits to themselves as well as an ethical dimension concerning the animals (Harper and Makatouni, 2002). Concerns for farm animal welfare, therefore, may be more likely to translate into community behaviour such as signing petitions (Coleman *et al.* 2005) or voting for animal welfare legislation (Lusk *et al.*, 2008). It is obviously important to regularly monitor public attitudes and for industry to respond by providing choice in the market place, providing information to consumers or changing practices.

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PART 3: UNDERSTANDING ANIMAL WELFARE: SCIENTIFIC PERSPECTIVES

Concepts of animal welfare

As noted by several authors there is considerable uncertainty within science (Sandøe *et al.*, 2004; Barnett and Hemsworth, 2009) or at least the lack of a consensus position among scientists (Fraser, 2003; 2008) on the concept of animal welfare. This uncertainty arises basically because scientists differ in their concept of animal welfare and thus how animal welfare should be measured or judged. There are three prominent concepts of animal welfare in the literature: the welfare of animals is judged on the basis of (1) how well the animal is performing from a biological functioning perspective; (2) affective states, such as suffering, pain and other feelings or emotions; and (3) the expression of normal or 'natural' behaviours. The so-called 'five freedoms', that is freedom from hunger and thirst, from discomfort, from pain, injury and disease, to express normal behaviour, and from fear and distress (FAWC, 1993) include aspects of all three of the animal welfare concepts described above. While most would accept that the these freedoms are necessary to avoid a lack of suffering, in terms of a consensus on animal welfare assessment, that there has been little attempt to define the levels of freedom that are desirable together with the adverse consequences of not providing such freedoms.

The first concept, which is often called the biological functioning concept, equates poor welfare to biological dysfunction. Broom (1986) defines the welfare of an animal as "its state as regards its attempts to cope with its environment". The 'state as regards attempts to cope' refers to both (1) how much has to be done in order to cope with the environment and includes biological responses such as the functioning of body repair systems, immunological defences, physiological stress responses and a variety of behavioural responses and (2) the extent to which these coping attempts are succeeding. This includes the lack of biological costs to the animal such as deterioration in growth efficiency, reproduction, health and freedom from injury. This definition of Broom's (1986) is not dissimilar from the one recently endorsed by the 172 member countries of the OIE (2008): "Animal welfare means how an animal is coping with the conditions in which it lives. An animal is in a good state of welfare if (as indicated by scientific evidence) it is healthy, comfortable, well nourished, safe, able to express innate behaviour, and if it is not suffering from unpleasant states such as pain, fear, and distress. Good animal welfare requires disease prevention and veterinary treatment, appropriate shelter, management, nutrition, humane handling and humane slaughter/killing. Animal welfare refers to the state of the animal; the treatment that an animal receives is covered by other terms such as animal care, animal husbandry, and humane treatment."

Using this concept of biological functioning, the basis of the approach to judge animal welfare is that difficult or inadequate adaptation will generate welfare problems for animals (Broom and Johnson, 1993; Barnett and Hemsworth, 2003) and therefore a broad examination of the behavioural, physiological, health and fitness responses of animals in reaction to the condition of interest (i.e. under study) can be undertaken to assess biological functioning of the animals. In other words, the risks to the welfare of an animal imposed by the condition of interest can be assessed at two levels (1) the magnitude of the behavioural and physiological responses and (2) the biological cost of these responses. These behavioural and physiological responses include the abnormal behaviours, such as stereotypies and redirected behaviours, and the stress response, respectively, while the biological cost includes adverse effects on the animal's ability to grow, reproduce and remain healthy and injury-free.

This approach to welfare assessment has been used by scientists to examine the effects of housing, husbandry and handling. For example, a broad examination of the behavioural, physiological, health and fitness responses in handling studies, particularly in pigs and poultry, have generally shown that negative or aversive handling, imposed briefly but regularly, will increase fear of humans and reduce growth, feed conversion efficiency, reproduction and health of these animals (see Hemsworth and Coleman, 1998; Waiblinger *et al.*, 2006; Hemsworth *et al.*, 2009). A chronic stress response has been implicated in these effects on productivity since in many of the pig handling studies (see Hemsworth and Coleman, 1998), handling treatments which resulted in high fear levels also produced either a sustained elevation in the basal free cortisol concentrations or an enlargement of the adrenal glands. Studies examining surgical husbandry procedure have also used a broad examination of the behavioural, physiological, health and fitness responses to study animal welfare (Mellor *et al.*,, 2000; Hemsworth *et al.*, 2009).

A common criticism of this concept of biological functioning is that it does not adequately include emotions. However, emotions are part of the body's regulatory system and together with a range of learning processes function to assist animals in avoiding potentially harmful situations or recognising potentially beneficial situations (Cabanac, 1979). The effects of aversive handling of farm animals indicate the profound effects of fear on stress physiology and fitness (see Hemsworth and Coleman, 1998) and a consistent finding in biological psychiatry is that the HPA axis physiology is altered in humans with major depression (see Parker *et al.*, 2003), for example a sustained elevation in basal cortisol concentrations.

The second concept, often called the affective state or feelings-based concept, defines animal welfare in terms of emotions and emphasizes reductions in negative emotions, such as pain and fear and frustration, and increases in positive emotions such as comfort and pleasure (Duncan and Fraser, 1997). Duncan (2004; 2005) has argued that animal welfare ultimately concerns animal feelings or emotions as follows. All living organisms have certain needs that have to be satisfied for the organism to survive, grow and reproduce and if these needs are not met, the organism will show symptoms of atrophy, ill-health and stress and may even die. Higher organisms (vertebrates and higher invertebrates) have evolved 'feelings' or subjective affective states that provide more flexible means for motivating behaviour to meet these needs.

Measuring preferences of animals, using preference tests, aversion learning and behavioural demand testing (Dawkins 1980; Matthews and Ladewig 1994; Kirkdon and Pajor, 2006), has been used by scientists to assess animal welfare predominantly on the basis that these preferences are influenced by the animal's emotions, which have evolved to motivate behaviour in order to avoid harm and facilitate survival, growth and reproduction. Preference testing using for example a Y-maze apparatus that allows a choice between access to two different resources has been used to provide information about specific features in the animal environment such as flooring (Hughes and Black, 1973; Hutson, 1981), restraint methods (e.g. Pollard *et al.*, 1994), handling treatments (Rushen, 1986) and ramp design (Phillips *et al.*, 1988), with the overriding objective of optimising the environment for animals. For laying hens it includes light sources (Widowski, *et al.*, 1992), ammonia levels

(Kristenson *et al.*, 2000), group size (Dawkins, 1982), perches (Lambe and Scott, 1998) and nest box design (Struelens *et al.*, 2005).

While the consistent choice or preference of one resource over another or others indicates the animal's relative preference, some have argued that a problem with examining animal preference is that the expression of a preference does not indicate how important the resource is to the animal (e.g. Matthews and Ladewig, 1994). 'Behavioural demand' studies, for example in which operant conditioning techniques such as pecking at a key or pushing through a weighted door have been used to allow the animal to learn to perform a response to gain access to a resource, have been used in an attempt to quantify the animal's level of motivation to access or avoid the situation being tested (Dawkins, 1983; Matthews and Ladewig, 1994; Fisher and Hogan, 2003). Many of these techniques were first developed using laying hens (Dawkins, 1983; Duncan and Kite, 1987; Lagadic and Faure, 1987; also see review by Cooper and Albentosa, 2003).

While not well enunciated, the third concept promotes the principle that animals should be allowed to express their normal behaviour. In the early literature, the view that animals should perform their full 'repertoire' of behaviour was very common, however there is broad agreement within science that it is often difficult to attribute actual suffering when the expression of certain behaviours is prevented or is absent when it would be expected to be present (Dawkins, 2003). Furthermore, as discussed by Dawkins (1980), 'wild' behaviour may represent an animal's efforts to survive in a life and death struggle or contest and therefore some 'natural' responses are adaptations to cope with extreme adverse situations.

Related to this notion of the importance of displaying normal behaviour is that of 'behavioural (or ethological) need'. The term 'behavioural need' arose in response to the Brambell Committee report where it was proposed that animals have "natural, instinctive urges and behaviour patterns" and that animals should not be kept in conditions that suppress these behaviour patterns (Brambell *et al.*, 1965). From its inception, the term was highly debated and often criticized for its lack of both clear definition and scientific foundation (Dawkins, 1983). Over time, there was some consensus that the term 'behavioural need' should refer to specific behaviour patterns that may be important for animals to perform and that, when prevented, would result in frustration or some negative psychological state that would cause suffering and impair welfare (Dawkins, 1983; Hughes and Duncan, 1988; Jensen and Toates, 1993). Dawkins (1990) and Fraser and Duncan (1998) suggested that behavioural 'need situations', that is behaviour associated with intense negative emotions, likely evolved for those behaviours where immediate action is necessary to cope with a threat to survival (e.g. escape from a predator) or reproductive fitness (e.g. nesting) while other types of behaviour that can be performed when opportunity arises (e.g. play, grooming) are more likely to be associated with positive emotional states. More recently the term 'behavioural need' has been used to refer to "instinctive behaviours that are performed even in the absence of an optimum environment or resource" (Weeks and Nicol, 2006; also LayWel 2006) and behavioural 'priorities' to refer to behaviour or resources that accommodate the behaviour (for example a nest box or litter) that animals have been shown to be willing to work for in demand studies (Cooper and Albentosa, 2003; Weeks and Nicol, 2006). By these latter definitions, any consequences of depriving the animal of performing the behaviours are not considered, which is an important distinction form earlier concepts of behavioural needs. For the laying hen, Weeks and Nicol (2006) suggested that while nesting is a behavioural 'priority', dust bathing perching and foraging are behavioural 'needs'. Thus, the consequences of depriving animals of the opportunity to perform these behaviours are not addressed; therefore, there still appears to be a lack of consensus on how to define and provide scientific evidence for behavioural 'needs'.

These different concepts or views on animal welfare can lead scientists to use different criteria or methodology in assessing an animal’s welfare. For short term animal welfare issues involving acute stress, such as painful husbandry procedures, there is considerable agreement on the need to assess animal welfare from a perspective of biological functioning (Mellor *et al.*, 2000). However, for longer term issues disagreement over these welfare concepts, especially when consequent interpretations conflict, lead to contentious debates concerning animal welfare and the varying interpretations.

Conceptual uncertainty

This uncertainty surrounding the concept of animal welfare and thus how animal welfare should be judged does not necessarily diminish the robustness of the research utilising methodologies or measurements promulgated by these views or concepts. However this conceptual uncertainty has several implications for identifying and resolving genuine risks to an animal's welfare (Barnett and Hemsworth, 2009) and these implications need to be recognised.

First, scientists have basically used two concepts and corresponding methodologies to study animal welfare. The main methodologies seen in the literature to study animal welfare are measurements of biological functioning and animal preferences. As discussed earlier, biological functioning involves a broad examination of the behavioural, physiological, health and fitness responses of animals in reaction to condition under study on the basis that difficult or inadequate adaptation will generate welfare problems for animals. The second methodology uses animal preference, aversion (and behavioural demand) testing on the basis that animal preferences are influenced by the animal's emotions, which have evolved to motivate behaviour in order to avoid harm and facilitate survival, growth and reproduction. Therefore, differences in concepts and thus definitions of animal welfare within science lead to differences in the methodology used by scientists to assess animal welfare under different husbandry or housing practices.

Second, differences between policy makers in their interpretation of the scientific literature can lead to disagreement on animal welfare-related policy and legislation. While decisions on specific animal use are affected by a number of considerations including scientific information of the harms and benefits to the animal (Mellor and Littin, 2004), this conceptual uncertainty can lead to differences between policy makers in industry, community groups and Government in their interpretation of the validity of scientific information arising from a specific methodology. Consequently, these differences between policy makers in interpreting similar information can lead to disagreement on setting or accepting specific animal welfare standards.

These conceptual differences at both scientific and policy levels are well illustrated in developments in housing systems for laying hens. A recent comprehensive review by European scientists of the literature (LayWel, 2006; Blokhuis *et al.*, 2007) provided recommendations on the welfare implications of housing systems for laying hens. The scientists used the five freedoms as a baseline for animal welfare assessment and considered 39 welfare risks under four main categories: injury, disease and pain; hunger, thirst and productivity; behaviour; and fear, stress and discomfort (Table 1). These risks were considered separately for conventional cages, furnished cages, single and multi-level non-cage systems and systems with an outdoor run. The report concluded that while all alternative systems have the potential to provide satisfactory welfare for laying hens, conventional cages cannot meet the welfare requirements of hens. However, from the documentation presented in the report, it can be argued that conventional cages perform better in 18 of the 39 risk areas, including those involving mortality, while non-cage and outdoor systems perform better in 9 and 10 categories, respectively, than conventional cages. The conventional cages perform worse for 6 of 7 categories of behaviour, but no evidence is presented that behaviour is more important to welfare than for example, mortality. However, the authors do state that a reason for their conclusion is that every individual hen in cages is affected by behavioural restriction whereas other advantages and disadvantages are less certain and seldom affect all individuals to a similar degree (Blokhuis *et al.*, 2007). Using similar interpretations, the European Union Council Directive 99/74/EC proposed that the use of conventional (unenriched) cages will be banned in the European Union by January 2012. In reviewing the development of hen welfare standards in the EU, Savory (2004) concluded that the freedom to 'perform normal behaviour' is often given more weight in interpreting welfare risks than the other four freedoms; for example, freedom from discomfort, pain, injury and disease.

Third, the use of credible measures in any welfare monitoring scheme in the field are critical in providing assurance on welfare standards to the industry, markets and regulatory authorities. The welfare measures or ‘tools’ that science develops to evaluate the welfare implications of husbandry and housing practices will obviously be incorporated into welfare standards, assessment and screening tools in the field. However, any uncertainty about the validity of the scientific measures on which the field measures are based may affect community, consumer, industry, community group and Government confidence in compliance with specific welfare standards.

While this uncertainty in relation to welfare concepts and resultant methodologies exists, it is clearly important that scientists provide the basis for their methodology used in studying animal welfare so that individuals using science in their decision-making appreciate both the rationale for the methodology and its limitations (Fraser, 2003; Sandøe *et al.*, 2004; Thompson, *et al.*, 2007).

Conclusions

This scientific uncertainty in relation to animal welfare concepts or views does not necessarily diminish the robustness of the research utilising criteria or methodologies promulgated by these different views or concepts. However, it does raise the question of the relatedness of these concepts (Barnett and Hemsworth, 2009). In other words, is biological dysfunction associated with or does it lead to negative affective states and vice versa? Thus, are the resultant methodologies measuring the same state(s) in the animal? Research utilising well-accepted stress models paired with carefully designed measures of affective states is required to understand the relationships between these concepts and methodologies.

In any consideration of animal welfare assessment, it is useful to reflect on society's objectives in relation to animal welfare. There is a long tradition of ethical thinking in relation to animal use and this has brought us to the present commonly held utilitarian view in many societies that animal management or use by humans is acceptable provided that such management or use is humane (Mellor and Littin, 2004). Thus the priority for many, which is unlikely to diminish in the future, is the avoidance of animal suffering. Notions, such as 'suffering', are often used without being clearly defined. The following two definitions appear to have broad support both in science and the general community. Morton (1998) has defined suffering in terms of 'prolonged adverse physiological and mental states in an animal' and Dawkins (1990) proposes that 'suffering occurs when unpleasant feelings are acute or continue for a long time because the animal is unable to carry out the actions that would normally reduce risks to life and reproduction in those circumstances'. This use of the term suggests that suffering is likely to be synonymous with impaired animal welfare. It is also important to recognise that there is an emerging shift in community values towards not merely minimising suffering in domesticated animals, but also enhancing pleasure in these animals (Tannenbaum, 2001). For many a consideration of animal welfare includes not only the avoidance of suffering, but also the presence of positive subjective emotional states (Duncan, 2004).

While society continues to struggle to identify and agree on minimum welfare standards for its domestic animals, the difficulty of agreeing on desirable animal welfare standards is clearly substantially greater. Nevertheless, the priority for the community is the avoidance of animal suffering. This mandate to avoid suffering is clearly evident in the prevention of cruelty legislation in many Western countries which specifically refers to cruelty in terms of “unreasonable pain or suffering” (e.g. Victoria, Australia (Anonymous, 2007)) or “unnecessary suffering” (the United Kingdom (Anonymous, 1911)). It should be recognised though that the legislation in many of these countries refers to its purpose as not only “to prevent cruelty to animals” but also “to encourage the considerate treatment of animals” (Anonymous, 2007).

In an ethical analysis of an animal use, science can provide the factual basis of understanding the impact of a husbandry or housing practice on the animal, particularly its impact on the welfare of the animal. However, there is considerable uncertainty within science on the concept of animal welfare and these different concepts can lead scientists to use different criteria or methodology in assessing an animal’s welfare. To assist in integrating these criteria and developing a broader consensus on animal welfare methodologies, research utilising well-accepted stress models must be coupled with carefully designed measures of affective states in order to understand the relationships between these concepts and methodologies. In the meantime, the approaches or methodologies that arise from the functioning-based and feeling-based concepts should guide current welfare research methodology. Indeed, while the general public may appreciate that long-term behavioural responses such as stereotypies and chronic stress are ‘harmful’, there is merit in understanding what animals prefer since as Fisher and Hogan (2003) note, “we all know which part (approach) will be the most powerful argument for the audience (general public)”. Furthermore, the basis of the methodology used by scientists to assess animal welfare should routinely be provided so that individuals using science in their decision-making appreciate both the rationale for the methodology and its limitations (Fraser, 2003; Sandøe *et al.,* 2004; Thompson *et al.*, 2007).

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Table 1. Estimated risks to the welfare of laying hens for a variety of factors compared across different housing systems as identified in the Laywel report (www.LayWel.eu). H- indicates a high risk for poor welfare; V- denotes a medium risk to welfare and a factor that is highly variable within the system or between farms; L – indicates low risk of poor welfare and a high probability of good or satisfactory welfare.

Indicator/Risk of poor welfare	**Conventional cage**	**Furnished cages**			**Non-cage (tier)**		**Free Range**
		Small	**medium**	**large**	**single**	**multi**	
Injury, disease, pain							
Mortality (overall %)	V	V	V	V	H	H	H
Mortality due to feather pecking/cannibalism in beak-trimmed flocks	L	V	V	V	V	V	V
Mortality due to feather pecking/cannibalism in non beak-trimmed flocks	V	V	H	H	H	H	H
Mortality due to disease	L	V	V	V	V	V	V
Infectious disease and use of therapeutic drugs	L	L	L	L	V	V	V
Predation	L	L	L	L	L	L	V
Internal parasites	L	L	L	L	H	H	H
External parasites	V	V	V	V	V	V	V
Use of prophylactic anthelmintics and coccidiostats	L	L	L	L	V	V	V
Osteoporosis/low bone strength	H	V	V	V	L	L	L
Keel bone deformation	L	V	V	V	V	V	V
Bone breaks during lay	L	V	V	V	H	H	H
Bone breaks at depopulation	H	H	H	H	V	V	V
Bumble foot	L	V	V	V	H	H	H
Beak trimming	V	V	H	H	H	H	H
Hunger, thirst and productivity							
Feed intake	L	L	L	L	L	L	L
Water intake (L)	L	L	L	L	L	L	V
Feed conversion ratio	V	V	V	V	V	V	V
Egg production (% hen day)	V	V	V	V	V	V	V

Indicator/Risk of poor welfare	Conventional cage	Furnished cages			Non-cage (tier)		Free Range
		Small	**medium**	**large**	**single**	**multi**	
Behaviour							
Nest box eggs at peak lay (%)	H	L	L	L	L	L	V
Hens on perch at night (%)	H	V	V	V	V	V	V
Use of dust bath	H	V	V	V	V	V	V
Foraging	H	V	V	V	L	L	L
Social	H	V	V	V	V	V	V
Behavioural restriction	H	V	V	V	V	V	L
Injurious pecking	V	V	V	V	V	V	V
Fear, stress, discomfort							
Fearfulness	H	V	V	V	V	V	V
Crowding/suffocation	L	L	L	V	H	V	V
Feather pecking in beak trimmed flocks	L	L	U	U	V	V	V
Feather pecking in non-beak trimmed flocks	H	H	U	U	H	H	V
Feather loss	V	V	V	V	V	V	V
Plumage soiling	L	L	L	L	V	V	V
Bumble foot	L	V	V	V	V	V	V
Thermal discomfort	V	V	V	V	V	V	V
Dust	L	V	V	V	H	H	V
Ammonia	L	V	V	V	V	V	V
Dirty eggs (%)	L	V	V	V	V	V	H
HIGH RISK OF POOR WELFARE (H)	10	2	3	3	9	8	7
VARIABLE/MEDIUM RISK OF POOR WELFARE (V)	9	25	23	24	22	23	26
LOW RISK OF POOR WELFARE (L)	18	10	9	8	6	6	4
UNKNOWN	0	0	2	2	0	0	0

PART 4: WELFARE ISSUES IN LAYING HEN PRODUCTION

Comparisons of the effects of different housing systems on animal welfare are difficult because of the wide variation across systems, and because specific design features within systems often have greater effects on welfare than differences between systems. In addition, it is important to recognize that scientists may differ in the degree of importance they place on measures of biological functioning, animal preferences and affective states as well as how they interpret research findings from these different methodologies. Therefore a comprehensive assessment of welfare should include available evidence from each of the different viewpoints and identify areas where different types of scientific evidence concur, where they conflict and where evidence is lacking. Rather than attempting to provide an overall assessment or ranking, we have identified some of the key welfare issues that are affected by different types of housing systems, and in the following sections, we review the scientific literature specific to those issues from each of the different approaches to studying animal welfare.

Space allowance, group size and stocking density

The minimum spatial need of an animal is for sufficient room to accommodate the animal's physical size and basic movement. In particular, this need is for the distances of length, breadth and height in which to stand, lie and articulate its major parts, including head, neck and limbs (Fraser and Broom, 1997). Furthermore, this consideration of spatial requirements should include sufficient space to enable the animal to effectively change posture (e.g. lie down) or turn around without injuring itself. In the context of laying hens, Dawkins and Hardie (1989) have shown that the minimum space used by laying hens to accommodate their size and basic movements is greater than provided in conventional cages. For example, using 1-4 birds per cage to modify floor space over the range of 450-6,724 cm^2/hen video records showed that birds used 540-1,006 cm^2 when turning, 653-1,118 cm^2/hen when stretching wings and 540-1,005 cm^2/bird when ground scratching. In addition to physical space, there is the need for personal space, which is the space needed to maintain some separation between the animal and its conspecifics (Fraser and Broom, 1997). The latter space is particularly important in group housing, but its relative importance to small and large groups is not known. Mench and Keeling (2001) in their review suggest the literature provides little evidence that birds have a personal space, although hens in groups do increasingly maximize the distance to their nearest neighbor as floor space allowance increases (Keeling, 1994). For example, Savory *et al.* (2006) found that average nearest neighbor distances in groups of 6 hens were around 20, 37, 44, 49, 51 and 53 cm between hens at space allowances of 600, 2400, 4800, 7200, 9600 and 12,000 cm^2/hen, respectively, with the rate of change leveling off at around 5000 cm^2/hen.

Thus, the above suggests that hens have a requirement for physical space to stretch and exercise muscles and may prefer to distance themselves from other birds. Furthermore, many species are motivated to separate several important functions, for example nesting away from the feeding area. Space may also be needed for body care or grooming and assisting in thermoregulation i.e. when hot. Thus, when considering spatial requirements for individual animals, it should also be recognized that the animal may have further spatial requirements other than those necessary for physical size and basic movement: they also have requirements for space to perform a range of behaviours that are likely to affect their welfare.

The literature on the effects of space allowance in layer cages shows that in general as floor space decreases, within a range of 300 to 650 cm^2 per caged laying hen, welfare generally decreases, based on either higher mortality, lower egg production and body weight or poorer feed conversion (see Hill, 1977; Hughes, 1983; Adams and Craig, 1985; Sohail *et al.*, 2004). An explanation, as suggested by Hughes (1983), is the reduced feeding space and in turn its effects on feed intake associated with a floor area reduction in cages of generally constant depth. Another explanation is that crowding may lead to elevated corticosterone concentrations, which in turn may adversely affect both production efficiency and health. Mench *et al.* (1986) reported that reducing space allowance in two-bird cages from 1394 to 697 cm^2/bird increased plasma corticosterone concentrations. Koelkebeck *et al.* (1987) reported an 11% increase in plasma corticosterone concentrations in caged hens when space allowance was decreased from 460 to 350 cm^2 per bird, although the increase was not statistically significant.

There is less information on the effects of space allowance in large groups. Surprisingly, in studies that had a relatively large space allowance per bird, there was a consistent trend for egg production to increase as space decreased from 2980 to 1580 cm^2/bird and from 1050 to 940 cm^2/bird (Appleby *et al.*, 1988). Al-Rawi and Craig (1975) showed a curvilinear relationship between space allowance from 412-2884 cm^2/bird and agonistic interactions, with fewer interactions at the lowest and highest space allowances and more interactions at intermediate space allowances of 824 and 1442 cm^2 per bird; group size was 4 for all area treatments. Nicol *et al.* (2006) found that mortality was lower but feather loss was worse in small commercial flocks (2450-3150 birds per flock) stocked at 12 birds/m^2 (833 cm^2/bird) compared to those stocked at either 7 birds/m^2 (1428 cm^2/bird) or 9 birds/m^2 (1111 cm^2/bird) in single-tiered aviaries. Egg production, feacal corticosterone and heterophil:lymphocyte ratios were not affected by stocking rate but stress measures at the end of lay were substantially elevated compared to the end of the rearing period, and the authors considered them to be at levels indicative of poor welfare at all of the stocking densities. Behavioural observations reported for those same flocks showed a density by age interaction with feather pecking and aggression being the highest in the low stocking density initially (at 30 weeks) but it increased with age so that there were no differences by 60 weeks of age (Zimmerman *et al.,* 2006). However, when Nicol *et al.* (1999) compared flocks ranging from 72 to 368 birds, at stocking densities of 6, 14, 22 or 30 birds/m^2 (1666 to 333 cm^2/bird), from 14 to 30 weeks of age, birds at 6 birds /m^2 had higher egg production at 23 weeks and better plumage condition at 30 weeks compared to birds at all of the other densities.

For caged hens, while there are studies that show detrimental effects of increasing group size in conventional cages from 4-28 birds per cage on agonistic pecking (Al-Rawi and Craig, 1975) and from 4-14 birds (space allowance in both studies of 412 cm^2 per bird) on agonistic pecking and mortality (Al-Rawi *et al.*, 1976) and in furnished cages from 4-5 to 8 birds per cage on feather pecking and mortality (Appleby *et al.*, 2002), similar effects were not apparent in another study in birds housed in furnished cages in groups of 5-8 (Abrahamsson and Tauson, 1997). Nevertheless, in a review of the literature by Mench and Keeling (2001), it was reported that increasing group size was associated with increased mortality, feather and skin damage and decreased egg production. Appleby (2004) recommended that groups of 10-12 were best for hen welfare in furnished cages as there was a larger total cage size, yet a lower risk of aggression among birds. Wall *et al.* (2004) acknowledged that the risk of aggression increased with group size and undertook a study to determine the effects of an 'escape area'. They compared hens in standard 16-bird furnished-cages with the same cage divided into two compartments by a partition with pop-holes. They found no welfare benefits based on heterophil:lymphocyte ratios as a measure of stress or feather condition as a measure of aggression.

In non-cage systems, aggression appears to be reduced in both small (0-20) and large (>100) groups (see Rodenburg *et al.*, 2005). A comparison of housing birds on the floor in groups of 15, 30 and 60 hens, found production problems with the intermediate group size of 30 hens (Keeling *et al.*, 2003). In her review of group life in animals, Lindberg (2001) makes some salient points on optimum group size. Groups of optimal size may vary in the wild because if there were such a group size it would pay for other individuals to join the group and increase it above optimal size (Sibly, 1983). This may result in unstable groups. Hence in nature, while groups may be stable they may be larger than optimum (Pulliam and Caraco, 1984). Dawkins (1982) refers to the elusive concept of preferred group size as a range of factors that will affect what is optimum for different individuals in a flock. Thus, the stability of groups, stocking density and features of the physical environment may be more important than group size *per se*.

While behaviour changes as a consequence of different housing systems, and presumably space and group size are integral to this, comfort behaviours, such as preening, body shaking, scratching, stretching and beak cleaning were found to be similar in cages and aviary systems (Hansen, 1994). Preening appears to be one of the behaviours performed when less space is available to hens (Dawkins and Hardie, 1989; Keeling, 1994). However, wing stretching, leg stretching and tail wagging increased in frequency when birds housed with less space were released from cages into larger cages/enclosures (Baxter, 1994; Nicol, 1987) and in furnished cages as stocking density was decreased (i.e. 2 and 8 hens in the same-sized cage that changed space allowance from 750 to 3000 cm^2 per hen; Albentosa and Cooper, 2004). Elson (2004) found better plumage condition as space allowance increased in furnished cages from 600 to 870 cm^2 per hen. The amount of vertical space provided may also be important. Although few differences in behaviour were found between cage heights of 38 and 45 cm (Cooper and

Albentosa, 2004; Albentosa *et al.*, 2007), Moinard *et al.* (1998) found stronger humurae and fewer bone breaks after slaughter in cages that were 60 versus 40 cm high.

A few studies have investigated hens' preferences for environmental space and the value that hens place on it (see Cooper and Albentosa, 2003). Nicol (1986) found that when given free choice among different sized cages, individual hens reared in floor pens spent more time in larger enclosures than in smaller ones, although the hens regularly visited and spent short periods of time in the small cages. Using an operant method Lagadic and Faure (1987) showed that groups of 4 hens would work to increase space above 400 cm^2 per hen, but only for 25% of the time, suggesting that there may be an intermittent preference for a large cage that is context dependant (Cooper and Albentosa, 2003). Faure (1991) also found that when hens were trained to peck at a key in order to increase their cage size, rearing condition had a significant effect. Hens reared in cages worked less to enlarge their cages than hens reared in floor pens. These studies suggest that birds may habituate to space restriction, however there have been no studies to date to determine whether rearing in cages at different space allowances affects either hens' preference for different sized cages or their physiological responses to different space allowances.

There are other factors that interact with space. High temperatures can be associated with increased mortalities and although more space can ameliorate the effects, the principal causes are poor cage design or inadequate environmental control. For example, there were reduced mortalities in furnished cages compared to conventional cages (at least 750 cm^2 including furniture versus 550 cm^2 floor space per hen, respectively), albeit in an environmentally controlled building, at temperatures up to 30 ºC where inadequate environmental control was considered to have exacerbated the situation (Guesdon and Faure, 2004).

In summary, within the lower end of the range of space allowance (near and just above hens' physical space requirement), there is good evidence that crowding affects various measures of biological function including measures of the stress response, productivity and mortality. Hens require an absolute amount of 3-dimensional space in order to be able to perform basic body movements. Hens may prefer an absolute to distance themselves from other birds, but their strength of motivation to do so has not been thoroughly investigated. The relationships among space, group size and behaviour such as aggression and feather pecking are not well understood, particularly in large groups. Further research on space allowance and group size is clearly warranted. Indeed, as indicated by Cooper and Albentosa (2004), depending on the value that hens place on activities such as foraging, dust bathing and wing flapping, it is not clear if the increased space provided in furnished cages will allow adequate expression of such behaviours. Furthermore, if social facilitation were shown to be a factor in the performance of these behaviours, the increased space in furnished cages would be even less likely to allow adequate expression of the behaviours.

Behaviour patterns constrained by conventional cages

In addition to concerns regarding the amount of space required to accommodate physical size, basic movements, and social spacing, conventional cages are criticized because of the lack of environmental resources necessary to accommodate basic behavioural activities that may be important for the welfare of hens. As indicated in a previous section, the four specific behavioural activities of concern are nesting, dustbathing, foraging and perching. Considerable research has been conducted in order to increase our understanding of why hens perform these activities, and how the absence of resources to support them may affect their welfare. For each of these activities, we review what we know about their development, causation and function as well as hens' preferences and strength of motivation to perform them. Then we review what evidence exists regarding the consequences, in terms of both affective states and biological function, of either accommodating or preventing hens from performing those activities.

Nesting

The pre-laying behaviour of hens has been studied extensively for well over 40 years beginning with the studies of Wood-Gush who showed that nesting is a natural reproductive behaviour stimulated by the hormonal events associated with ovulation, resulting in an organized sequence of behaviour prior to oviposition on the following day (see Wood-Gush and Gilbert, 1964; Gilbert and Wood-Gush, 1968).

Hens begin to show signs of searching for a nest site several hours prior to egg laying. The searching phase is characterized by increased locomotion and examination of potential nesting sites. The searching phase is followed by a period of sitting at the site where the egg is laid. Other elements of nest building and nest construction such as pecking and arranging of substrate and rotation of the body in the nest accompany sitting (Duncan and Kite, 1989).

Most hens prefer to lay their eggs in a discrete enclosed nest box and the strength of hens' motivation to access a nest box has been demonstrated in a variety of ways (see recent reviews by Cooper and Albentosa, 2003; Weeks and Nicol, 2006). Hens have been shown to be willing to squeeze through narrow gaps (Cooper and Appleby, 1997), push open weighted doors (Follensbee, *et al.* 1992), and pass through cages occupied by unfamiliar or dominant hens in order to gain access to a nest box (Freire *et al.*, 1997a), tasks considered costly or aversive to hens. Hens are only weakly motivated to reach the nest site during the searching phase, although motivation to gain access to a nest increases at the end of the searching phase, that is, near the start of the sitting phase preceding oviposition (Freire *et al.*, 1997b; Cooper and Appleby, 2003). Cooper and Appleby (2003) showed that ISA Brown hens' work-rate (by pushing through a locked door) for a small pen furnished with a nest box nest pen at 40 min before expected time of egg-laying was equal to their work-rate to return to their home pen after 4 h of confinement without food, and the work rate to access the nest was double that amount at 20 min prior to oviposition.

There are strain differences in pre-laying behaviour with medium hybrids typically laying more floor eggs than light hybrid hens (Appleby *et al.*, 2004), which may indicate differences in nesting motivation. For example, while light hybrids, medium hybrids and broiler breeder hens were all willing to push-though a weighted door to access a nest box, the medium hybrid hens showed less persistence at the task than hens of the other strains (Follensbee *et al.*, 1992).

In conventional cages or when a nest box is not available hens are more active, engage in locomotory behaviour for a longer duration before laying their eggs, and often perform what has been described as stereotyped pacing; behavioural differences that have been interpreted as signs of frustration (Wood-Gush and Gilbert, 1969; Zimmerman *et al.*, 2000; Yue and Duncan, 2003; also see Appleby *et al.*, 2004).

These behaviour patterns are typically more pronounced in light hybrids than in medium hybrid hens although medium hybrid hens are also observed to begin sitting in a cage and then go through the motions of rotating and arranging nesting material even in the absence of substrate, a behaviour referred to as vacuum nest building. (Appleby *et al.*, 2004).

Zimmerman *et al.* (2000) reported a significantly higher frequency of “gakel calls” when hens were 'thwarted' from nesting by removing them from their nest boxes during the sitting phase of pre-laying behaviour The gakel call is a vocalization suggested to be indicative of frustration in hens (Zimmerman and Koene 1998; Keeling, 2004). However, this same call, also referred to as the pre-laying call, is typically given during the searching phase of pre-laying behaviour when hens are housed in floor pens with nest boxes (Wood-Gush and Gilbert, 1969). Therefore it is difficult to conclude whether this vocalization reflects frustration within the context of nesting. Yue and Duncan (2003) compared pacing behaviour of hens in cages with a nest box, without a nest box and when access to the nest box was blocked over three 7-day periods when hens were 28, 32 and 36 weeks of age. Hens with access to the nest box spent significantly less time pacing during the hour before oviposition (7%) compared to hens who had never experienced a nest box (23%) or who had their nest box blocked (20%), and their was no difference in behaviour over time suggesting that hens did not adapt, at least behaviourally, to the lack of a nest box.

Although these laboratory studies indicate that hens are motivated to lay their eggs in a nest box, the use of nest boxes by hens in furnished cages and in non-cage systems has been found to be highly variable depending on the study and system investigated. For example, the incidence of floor eggs in cages with a nest box has been reported to range from 10-57% (Wall *et al.*, 2002; Guesdon and Faure, 2004; Cronin *et al.*, 2005) but there are also reports of close to 100% nest use in some furnished cages (see Tauson, 2005). In Sweden, where commercial furnished cages are in current use, a report by Tauson and Holm (2002) on assessment of animal welfare in a total of 21 experimental and field studies showed that eggs laid in the nest was generally greater than 90% and often close to 100%. Incidence of floor eggs was reported to range from 0.7 and 18.4% in an aviary system (Abrahamsson and Tauson, 1998). A number of factors have been shown to affect both the attractiveness of and access to nest boxes by hens and include specific features of the nest, social factors, strain, age and rearing experience of the bird.

In furnished cages, the specific design of the nest box as well as the cage layout affect its use (Appleby *et al.*, 2004; Barnett *et al.*, 2009; Tauson, 2005). Both the degree of seclusion and the substrate lining the nest box are important. For example, more eggs were laid in enclosed nest boxes compared with nest areas constructed of turf-lined hollows in furnished cages (Appleby *et al.*, 2002). Artificial turf is commonly used as a lining in nest boxes and has been recently shown to be as attractive as peat moss, both of which were preferred by hens over plastic coated wire mesh (Streulins *et al.*, 2005). In the same study, the addition of plastic flaps at the nest box entrance did not affect where eggs were laid but increasing the degree of enclosure with flaps resulted in a lower frequency of entries, longer stays and increased nestbuilding behaviour in the form of scraping and scratching (Struelins *et al.*, 2008). While more eggs are laid in nests lined with artificial turf than those with wire floors (Abrahamsson *et al.*, 1996), the proportion of the nest that is lined with artificial turf has also been shown to affect nest usage with significantly more eggs being laid in the nest when a greater proportion of the floor is lined with turf (Wall and Tauson, 2002; Wall *et al.*, 2002). The interaction of different furnishings in cages can also affect nest use. For example, Barnett *et al.* (2009) showed that nest use increased when (furnished) cages also included perches.

Social factors such as gregariousness and dominance status can affect pre-laying behaviour and access to a nest site (Sherwin and Nicol, 1993; Freire *et al.*, 1998; Cordiner and Savory, 2001; Shimmura *et al.*, 2007a). Dominant hens may show less unsettled pre-laying behaviour and use the nest box for longer durations than subordinate hens (Lundberg and Keeling, 1999). During observation of behaviour of hens in 25 commercial aviaries, Oden *et al.* (2002) reported that there was considerable aggression outside the nest boxes, and they suggested there was competition for nest boxes. As the majority of hens will lay their eggs within a window of time in the early part of the day, nest boxes should be able to accommodate multiple hens engaged in pre-laying behaviour. Appleby (2004) presented a theoretical model of nest area requirements using a minimum of 300 cm^2 of nest space per hen. Based on the probabilities of hens nesting simultaneously, he predicted various nest area requirements of hens for different group sizes ranging from 900 cm^2 (3 nest spaces) for groups of three hens to 2100 cm^2, or a total of 7 nest spaces, for a group of 12 hens. Increased aggression outside the nest box may be a result of the activity levels at the entrance rather than competition *per se*. When nest boxes were enclosed with plastic flaps and hens made fewer entries and settled sooner, aggressive pecking was also reduced (Struelins *et al.*, 2008)

Medium hybrids typically lay fewer eggs in nest boxes (Abrahamsson *et al.*, 1996; Appleby *et al.*, 2004), which corresponds to the studies on the effects of strain on nesting motivation. However, all strains of birds tend to increase their use of nests with age or experience over time (Sherwin and Nicol, 1993; Appleby *et al.*, 2002; Cronin *et al.*, 2007). On an individual hen basis, hens appear to be consistent in their choice of nest site by their tenth egg (Cronin *et al.*, 2007). Rearing experience may also affect use of nest boxes. For example, Sherwin and Nicol (1993) found that hens reared on litter laid more floor eggs in furnished cages than hens reared on wire. In non-cage systems where hens have to negotiate perches or more complex environments in order to access nest boxes, rearing in systems that encourage use of 3-dimensional space reduces floor eggs (Abrahamsson and Tauson, 1998; Gunnarsson *et al.*,1999; Tauson, 2005; Colson *et al.*, 2008).

Even when nest designs shown to be attractive to birds are used, some hens consistently choose not to lay their eggs in the nest box (Sherwin and Nicol, 1993; Cooper and Appleby, 1997; Cronin *et al.*, 2007). For example, Cronin *et al.* (2007) observed individual egg-laying patterns in 56 Hy-Line Brown hens housed in groups of 2, 4 or 8 hens in cages with a nest box. Hens showed a consistent choice in egg-laying site. From the 11^{th} to the 40^{th} egg, 66% of hens consistently (at least 80% of their eggs) laid in the nest box and 27% of hens consistently laid on the wire floor in an area equivalent in size to the nest box. Whether this behaviour is due to a generally low motivation to use a nest box or a difference in what constitutes an attractive nest site to these particular birds is not known (Cooper and Albentosa, 2003). However, the latter (attractiveness of nest site) is unlikely as the nest and cages used in Cronin's study were similar to those in the report of Tauson and Holm (2002) where nest box use was generally greater than 90%.

Cooper and Appleby (1997) compared the motivation of consistent versus inconsistent nest box layers to access a tunnel by squeezing through a narrow gap in order to perform more locomotion and searching during the pre-laying period.

Consistent nest layers accessed the tunnel less often and settled in an enclosed nest box more quickly while inconsistent nest layers persisted in accessing the tunnel and continued searching even when a nest box was available. These authors concluded that inconsistent nest layers were in fact motivated to nest but their perception of what constituted a satisfactory nest differed. Similarly, Cronin *et al.* (2005) found that floor layers in furnished cages stood more, walked more and covered more areas of the cage during the last 30 min before laying their eggs than did nest box layers. Nevertheless, Cronin *et al.* (2007) also showed that most hens (93%) were consistent in their choice of nest site whether it be the nest box or the wire floor outside of the nest box, as reported above. These findings are supported by recent work by Zupan *et al.* (2008) who found that nest layers (who prefer an enclosed nest box) and litter layers (who prefer to lay in an open tray of litter) were consistent in their choices, and that litter layers were more active than nest layers prior to oviposition. In a study aimed at measuring strength of their preferences, litter layers were as motivated to gain access to their preferred nest type as were nest layers when they had to push through a weighted door (Kruschwitz *et al.*, 2008), and nearly all hens in both populations chose the less preferred type of nest when the resistance on the door became too high.

Based on evidence of strength of motivation to lay in a nest box, differences in pre-laying behaviours in the absence of a nest and increased vocalizations when access to a nest is blocked, it has been concluded that there is convincing evidence of the importance of a suitable nest site and that welfare is reduced when a 'suitable' nest box is not available (Appleby, 1993, 1998a; Duncan, 2001; Keeling, 2004; Weeks and Nicol, 2006). However, corroborating physiological evidence of frustration or some negative affective state would strengthen the argument for reduced welfare in the absence of a nest box (Cooper and Albentosa, 2003; Duncan, 2005). This is because negative affective states of animals such as pain, fear and frustration are often accompanied by visceral or endocrine changes indicative of a stress response (Dantzer, 2002; Desire *et al.*, 2002). Surprisingly few scientists have attempted to measure physiological responses to denying hens access to a nest box or other resources that enable hens to perform nesting behaviour.

A range of environmental and psychological stressors are known to cause delays in expected time of oviposition with consequent effects on egg shell quality (see review by Roberts, 2004). Delayed oviposition is due to retention of the egg in the shell gland (uterus), which is caused by the release of adrenaline during an acute stress response. Moving hens to a strange cage with unfamiliar hens prior to egg laying, for example, causes a significant delay in time of oviposition which can be reversed by administration of propranolol, a pharmacologic agent that blocks ß-adrenergic receptors in the shell gland (Reynard and Savory, 1997). A change in egg shell colour or quality can be used as an indirect measure of delayed oviposition because additional time in the uterus after the cuticle on the egg has been laid down can result in a deposit of extra-cuticular calcium. Therefore, a delay in oviposition can be quantified either by directly observing the actual versus expected time of egg laying, or it can be estimated indirectly by quantifying the degree of extra-cuticular calcification on the egg (Hughes *et al.*, 1986; Reynard and Savory, 1999). Quantification of extra-cuticular calcium can be accomplished by subjectively scoring brown eggs for a pink, dusted or banded appearance (Hughes *et al.*, 1986) or by use of light refractometer that measures lightness in colour (Reynard and Savory, 1999). Chemical means of quantifying extra-cuticular calcium has also been used for white eggs (Yue and Duncan, 2003).

Several studies investigating motivation to nest have shown a delay in oviposition when nesting is disrupted, but this effect appears to be dependent on the phase of pre-laying behaviour. Cooper and Appleby (2003) found that delaying access to a nest until 40 or 20 min prior to the expected time of oviposition significantly increased the time between successive eggs compared to when hens were given access to the nest at 60 or 80 min prior to expected oviposition. Similarly when laying hens were presented with food at various times before egg laying, delayed oviposition was observed when pre-laying behaviour was interrupted during the sitting phase (Freire *et al.*, 1997b). Sheppard (2003) delayed feeding of broiler breeders until hens were observed to be sitting on nests. Most hens left the nest boxes to eat but returned to them to lay their eggs. Scores for extra-cuticular calcium were significantly higher for eggs collected on days when feeding was delayed compared to those collected on control days when hens were fed earlier. Therefore delays in oviposition appear to occur mainly from disruptions to nesting occurring during the period when hens are most motivated to nest.

Only two studies have used extra-cuticular calcium to compare the responses of hens housed with and without access to enclosed nest boxes. In one study egg *colour* was, in fact, associated with nest box design (Walker and Hughes, 1998); in cages furnished with either enclosed nest boxes or open nest hollows, 80% of eggs were laid in enclosed nests compared with 41% in laid in nest hollows. Egg colour, measured by reflectance of the eggs was significantly lighter (indicating more extra-cuticular calcium) for eggs collected from hens with the open, less attractive, nest hollows than for eggs from hens with enclosed nest boxes. However, Yue and Duncan (2003) found no difference in extra-cuticular calcium on shells from hens from cages with or without nest boxes, or from hens blocked from using their usual nest box.

Few studies have specifically addressed the effects of furnished versus conventional cages with regard to nesting, on other physiological parameters. In two studies, no differences were found due to the presence of furniture, including a nest box, when adrenal responsiveness was measured (Guesdon *et al.*, 2004; Barnett *et al.*, 2009). However, in one of those studies mesh flooring was used in the nest box and nest box usage was extremely low (44%) (Guesdon and Faure, 2004). In an experiment specifically comparing hens in cages with and without nest boxes, Cronin *et al.* (2008) found that hens in cages with a nest box had 33% higher plasma corticosterone concentrations than hens without nest boxes early in lay at 23 weeks of age and suggested that the elevated stress response in cages with nest boxes was probably associated with social factors, i.e. competition for the nest box. When hens that were accustomed to laying in a nest box were denied access to the nest, egg albumen corticosterone concentrations were not different from controls during the first 2 days, were significantly higher on day 3 but were similar again on day 7 (Cronin *et al.*, 2008). The authors concluded that there were no long-term adverse effects on stress physiology between hens with or without a nest-box, or those subsequently prevented from laying in a nest box.

Although productivity has been compared among different housing systems, few studies have specifically assessed the effects of a nest box on performance. In general, comparisons of furnished and conventional cages show no consistent differences in egg production, although the numbers of cracked and downgraded eggs can be greater in furnished cages and are dependent on cage design (Appleby *et al.* 2002; Tauson, 2002).

In summary, motivation for nesting has been studied extensively and a number of studies using preference and behavioural demand tests concur that most hens prefer and are highly motivated to access an enclosed nest site. Individual and strain differences in nesting motivation and nest box use are not well understood. Although absence of a nest box results in behavioural differences that may be indicative of a negative affective state, there has been little research to date that assesses whether either an acute or chronic stress response is associated with lack of access to an enclosed nest.

Dust bathing

There has been considerable research on the development and control of dust bathing behaviour which has been reviewed by Olsson and Keeling (2005). Domestic fowl begin to show dust-bathing behaviour during the first weeks after hatching. The behaviour involves a sequence of motor patterns directed at litter that distribute substrate under the feathers and functions to remove feather lipids and maintain plumage condition (Sandilands *et al.*, 2004). In the absence of substrate, hens in conventional cages perform the sequence of dust bathing motor patterns on wire, referred to as vacuum or sham dust bathing (see Olsson and Keeling, 2005).

A hen's motivation to dust bathe is affected by a complex interaction of internal and environmental factors. Dust bathing occurs on average every 2 days and follows a diurnal rhythm, with most dust bathing occurring in the late morning and early afternoon (for example, Lindberg and Nicol, 1997). When birds have been kept without substrate for dust bathing, the latency to dust bathe is shortened and they perform longer and more intense dust bathing bouts when presented with a substrate. This is often referred to as a rebound effect and is considered to be evidence of a 'build up' of dust bathing motivation after a period of deprivation (Cooper and Albentosa, 2003). Surprisingly, the build up of feather lipids appears to have a minor role in control of dustbathing. Although van Liere *et al.* (1991) showed a modest (but significant) increase in dustbathing when uropygial (preen) gland oil was applied to hens' feathers, there was no difference in the dustbathing behaviour when feathered and genetically featherless chicks were compared (Vestergaard *et al.*, 1999). A number of environmental factors also affect hens' motivation to dust bathe including the sight of a dusty substrate (Petherick *et al.*, 1995), ambient temperature, light and a radiant heat source (Duncan *et al.*, 1998). External factors can be potent stimuli for dust bathing and the behaviour can essentially be 'switched on' under the right conditions. Groups of birds often perform dust bathing simultaneously, indicating that the behaviour may be socially facilitated but the role of social factors in a hen's motivation to dust bathe is still unclear (Duncan *et al.*, 1998; Olsson *et al.*, 2002a; Lundberg and Keeling, 2003).

The willingness of hens to work for a dust bathing substrate after a period of deprivation has been tested using a variety of operant and obstruction tests with variable and generally inconsistent results (see Widowski and Duncan, 2000; and reviews by Cooper and Albentosa, 2003; Olsson and Keeling, 2005). One problem concerning interpretation of motivation tests for access to dust bathing substrate is that hens may value material for foraging as well as dust bathing so it is difficult to distinguish why hens are working to gain access to litter. Another limitation with these tests is that hens are usually exposed to the sight of a dusty substrate during the test so it is difficult to draw conclusions as to whether 'out of sight is out of mind' for hens in cages. Widowski and Duncan (2000) found considerable individual variation in hens' willingness to push through a weighted door to access peat moss in a dust bath. Although the majority of hens tended to push more weight after they had been deprived of litter, some pushed through the door immediately after dust bathing in their home pen or pushed through the door and did not perform dust bathing. These authors concluded that these results do not support a 'needs' model of motivation for dust bathing but rather that hens dust bathe when the opportunity presents itself, however the behaviour is likely to be rewarding to the hens. Olsson and Keeling (2005) argue that the 'need' versus 'opportunity' model for dust bathing is more likely to depend on the internal state of the hen. They suggest that if a hen is presented with highly attractive substrate she may perform the behaviour even if she has recently dust bathed. However, when deprived of substrate for some time, the need to dust bathe will cause her to perform sham dust bathing in the absence of substrate.

Considerable early work addressed the preferences of birds for different dust bathing substrates (see Olsson and Keeling, 2005) with birds generally preferring to dust bathe in substrates with small particle sizes such as peat moss and sand over wood shavings or straw. Preferences can be influenced by rearing experience with birds presumably learning to recognize dust-bathing substrates early in life. However, Nørgard-Nielsen (1997) and Nicol *et al.* (2001) found that adult experience superseded exposure early in life and suggested that dust-bathing behaviour is fairly flexible. de Jong *et al.* (2007) measured the strength of preferences for wire, sand, wood shavings or peat moss. Hens were kept in wire-floor home pens with continuous access to the four resources that could be accessed by pushing through weighted doors. Neither the amount of weight pushed, the numbers of visits nor the total work hens were willing to expend to gain access differed among the different resources. Hens worked just as hard to gain access to wire as they did for loose substrates. When hens performed dust bathing after accessing a substrate, in almost all cases they worked to gain access to peat moss and no hens showed dust bathing on wire, but as the weight of the door was increased, frequency of dust bathing significantly declined. These results confirm earlier studies that hens prefer peat moss to other substrates for dust bathing but that accessing substrate for dust bathing is not a high priority.

In furnished cages when an area of litter or sand substrate is provided, a large proportion of hens are observed to perform dust bathing on wire floors (Abrahamsson and Tauson, 1997; Lindberg and Nicol, 1997; Shimmura *et al.*, 2007b). Most of this 'sham' dust bathing occurs at the front of the cage near the feed trough and includes bill raking in the feed as part of the dust bathing sequence; therefore it appears as if birds view the feed as a dust bathing substrate (Lindberg and Nicol, 1997; Olsson and Keeling, 2005). Access to dust baths is usually restricted to prevent egg laying in the baths (Tauson, 2002) but even when hens have been provided free access to dustbaths, 67% of dust bathing bouts were observed on wire (compared to 90% when access was restricted) (Lindberg and Nicol, 1997). Although it has been suggested that this sham dust bathing on wire may actually satisfy dust bathing motivation (see Olsson and Keeling, 2005), Olsson *et al.* (2002b) found both the latency to and duration of dust bathing in hens that had just finished sham dusting was similar to that of hens that had not dust bathed but significantly different from hens who had dust bathed in litter when all birds were subsequently offered litter.

Another explanation for sham dust bathing in furnished cages is that there is social competition for the dust baths. Dominant hens have been observed to use dust baths more than subordinate hens (Shimmura *et al.*, 2007a). However, Olsson and Keeling (2002a) found that sham dust bathing in furnished cages rarely occurred when another hen occupied the dust bath. Sham dust bathing in furnished cages may also be explained by the size or design of the dust bath or by the depletion of substrate within it (Lindberg and Nicol, 1997). Management of dust baths tends to be problematic in furnished cages, and Lindberg and Nicol (1997) suggested that it might be possible to provide an alternative section of flooring to accommodate sham dust bathing. Recent work by Merrill and Nicol (2005) and Merrill *et al.* (2006) has addressed the preferences of hens for dust bathing on different floor types in furnished cages. When groups of hens were given access to both a wire floor and a floor covered in artificial turf sprinkled with sand, all but 6 of 80 the hens observed during the study performed most or all of their dust bathing on the turf.

Although the appearance of sham dust bathing indicates that hens are motivated to perform the behaviour, there is very little evidence that hens experience frustration or some negative affective state from being deprived of dust bathing in substrate. Behaviour considered to be indicative of frustration in hens such as stereotyped pacing, head flicking or displacement preening has rarely been reported in studies on deprivation of dust bathing. Zimmerman *et al.* (2000) reported a higher number of gakel calls when thwarting dust bathing, but they also observed significantly less pacing and no differences in escape attempts, alarm cackles or displacement preening during the period of 'frustration' compared with 'pre-frustration' conditions.

Few studies have addressed evidence for a stress response or changes in other physiological measures associated with dust bathing deprivation. Vestergaard *et al.* (1997) compared the stress response of hens that had been reared and kept on wire or with sand for nearly three years when subsequently provided with either sand (wire-housed birds) or wire floors (sand-housed birds). Baseline corticosterone concentrations were not different between groups, but sand-housed birds had significantly higher concentrations of plasma corticosterone following the move. Although these results may indicate that hens that had access to sand may find a move to wire stressful, they do not indicate whether the response is associated with deprivation of dust bathing *per se* (Olsson and Keeling, 2005). Barnett *et al.* (2009) found no differences between hens in furnished cages with or without dust baths on plasma corticosterone or measures of immune response. Guesdon *et al.* (2004) also found no differences in adrenal responsiveness when comparing several styles of furnished and conventional cages, although furnished cages also included perches and nest boxes so that any affects specific to dust bathing could not be determined.

To date, the only functional consequence of the absence of dust baths that has been clearly demonstrated is a significantly higher concentration of lipids on the feathers of hens in conventional cages compared to hens housed on litter (Sandilands and Savory, 2000; Sandilands *et al.*, 2004). van Liere (1992) suggests that dust baths are essential to maintain feather integrity. Although deprivation of dust bathing during development has been suggested to be a cause for feather pecking (Larsen *et al.*, 2000), the current view is that feather pecking is more likely a consequence of reduced opportunity for foraging (see next sections).

Most aviary systems provide an area of litter where dust bathing can be performed, although some reports indicate that space in litter areas may be limited or that litter becomes caked and inappropriate for dustbathing (Oden *et al.*, 2002), particularly at high stocking densities (Carmichael *et al.*, 1999). Although wood shavings are not a preferred dustbathing substrate they are often used as the litter substrate in non-cage systems. Moesta *et al.* (2008) showed that dustbathing behaviour is stimulated more easily by used than by fresh wood shavings, as the shavings get soiled with feces and increased in the proportion of particulate matter over time. Colson *et al.* (2007) recently showed that, during tests, hens from conventional cages dust bathed more quickly and for a longer duration than hens from an aviary system indicating that motivation to dust bathe is, in fact, better satisfied in non-cage systems with litter than in conventional cages.

In summary, there is substantial evidence that hens are generally motivated to dust bathe irrespective of environment however there are clear preferences for different types of dust bathing substrate. In contrast to nesting, behavioural demand and obstruction tests have indicated that hens' strength of motivation to obtain substrate is not high. The role and significance of sham dustbathing is not well understood. There is currently no clear evidence of frustration, negative affect or stress in response to deprivation of dust bathing in a substrate. There are long-term consequences on feather lipids but whether these influence other aspects of health or biological fitness has not been explored.

Foraging

The feeding behaviour of domestic poultry in commercial settings is organised into short feeding bouts and shows a diurnal rhythm (Savory, 1979). Laying hens usually feed more towards the end of the day but non-layers tend to feed more in the morning, suggesting that the reproductive state of the bird has an impact on the feeding pattern (Broom and Fraser, 2007). The foraging behaviour of fowl consists of two components, an appetitive component involving scratching and pecking the substrate and a consummatory component involving the ingestion of food (Appleby *et al.*, 2004).

Hens in free-range settings usually scratch backwards two to three times and then step backwards to peck at the ground that they have just scratched (Broom and Fraser, 2007). In contrast, hens housed in conventional cages are unable to perform the appetitive component of foraging, although Appleby *et al.* (2004) suggest that the common manipulation by caged hens of feed from side to side in the feed trough, may represent the appetitive component of foraging behaviour. While red jungle fowl in a semi-natural environment have been shown to spend a large proportion of the day foraging (Dawkins, 1989), domesticated breeds of fowl show less foraging behaviour than less domesticated breeds in semi-natural settings (Schutz and Jensen, 2001).

Investigations of hens' preferences for different foraging materials and their strength of motivation to access different substrates using a variety of methods have provided conflicting results (see Cooper and Albentosa, 2003). Early work using operant techniques to obtain access to litter for pecking and scratching suggested that hens placed little value on access to foraging material (for examples Dawkins and Beardsley, 1986; Faure, 1991), although Gunnarsson *et al.* (2000a) found that hens would key peck to obtain access to straw and suggested that hens place a high demand for a litter substrate. Recent work measuring the strength of preferences of hens to access different substrates by passing through weighted doors from a home pen with wire flooring showed that neither the frequencies nor durations of time spent on sand, wood shavings, peat moss or wire floors differed; as weight on the doors increased, hens' visits to the different resources decreased at similar rates (de Jong *et al.*, 2007).

There is no obvious physiological evidence in the literature that indicates that a lack of foraging opportunities affects bird welfare. However, feather pecking has been viewed by some as a form of redirected behaviour in the absence of adequate foraging opportunities and some authors have proposed that feeding behaviour is redirected towards feathers in the absence of adequate foraging incentives (Hoffmeyer, 1969; Blokhuis, 1986; Blokhuis and van der Haar, 1989). A number of studies have shown that the provision of litter reduces feather pecking. Blokhuis and Arkes (1984) found that birds housed on slatted floors showed more feather pecking than those housed on litter. Moreover, feather pecking developed when hens were transferred from pens with litter to pens with slatted floors. Both Blokhuis and van der Haar (1989) and Johnsen *et al.* (1998) found that hens reared on wire floors showed a higher frequency of feather pecking than those reared on litter. Nicol *et al.* (2001) found that adult laying hens that had not been housed on wood shavings performed more feather pecking than those that had been briefly housed on shavings during rearing. However, adult hens housed on shavings performed less feather pecking than birds on wire floors, regardless of previous rearing experience. Huber-Eicher and Wechsler (1997) found that that provision of straw, an attractive substrate for foraging, reduced the frequency of feather pecking up to 7 weeks of age, while Huber-Eicher and Wechsler (1998) found that both the quantity and quality of foraging material promoted foraging and reduced feather pecking.

Furthermore, Huber-Eicher and Wechsler (1997, 1998) found that feather pecking in groups of hens was inversely related to the foraging activity. In contrast, Newberry *et al.* (2007) in a longitudinal study on the development of severe feather pecking in individual domestic fowl, found a positive association between foraging when young and severe feather pecking when adult, and a negative association between dust bathing when young and severe feather pecking when adult. The authors concluded that severe feather pecking did not substitute for foraging behaviour but, rather, that birds that performed relatively more foraging, and less resting and dust bathing, when young were more likely to perform severe feather pecking as adults. Thus while provision of litter reduces feather pecking, the results of Newberry *et al.* (2007) suggest that severe feather pecking does not substitute for foraging behaviour at the level of the individual bird. Feather pecking is specifically discussed later in this review.

In summary, foraging in the form of pecking and scratching in substrate is the appetitive component of natural feeding behaviour, although domesticated fowl show less foraging behaviour than their wild ancestors. While elements of pecking and scratching are observed in hens in cages, the body of evidence from preference and behavioural demand tests is largely contradictory and suggests that modern laying hens are not strongly motivated to obtain litter substrates to forage in. Although there appear to be no obvious physiological consequences from lack of foraging opportunities, there is considerable evidence to suggest that rearing and/or housing hens in the absence of foraging substrate either contributes to or exacerbates the development of feather pecking.

Perching

Although domestic fowl are primarily a ground dwelling species, the birds commonly roost together on tree branches at night and perch while resting during the day; this perching behaviour is considered to function in predator avoidance (Newberry at el., 2001). Perching behaviour develops within the first few weeks of life. In natural conditions, feral chicks have been observed to follow the hens onto high tree branches at around 6 weeks of age (Wood-Gush and Duncan, 1976). Onset of perching by chicks in floor pens has been observed to begin around one to two weeks of age during the day with night-time perching developing at around three to four weeks of age, although age at onset of perching can be influenced by the presence or absence of a broody hen, location of heat lamps and the heights of the available of perches (Heikkilä *et al.*, 2006; Riber, *et al.*, 2007). There is a learning component to perching behaviour; hens without perching experience during rearing are less adept at using perches (Appleby and Duncan, 1989) and have poorer spatial skills (Gunnarsson, *et al.*, 2000b) as adults.

There have been relatively few studies regarding hens' motivation to perch or any behavioural consequences arising from deprivation of perching behaviour (Cooper and Albentosa, 2003). When a perch is present either in pens (Newberry *et al.*, 2001) or a furnished cage (Appleby *et al.*, 1993; Tauson *et al.*, 2002) it is well used by hens, particularly at night. Only one study to date has measured strength of motivation to perch and it provided some evidence that group housed hens will ‘work’ harder to access a perch for use at night than for covered perch stands on which they could not perch (Olsson and Keeling, 2002b). When perches were removed from the pens of hens that were accustomed to perching, hens took longer to settle and made attempts to fly up suggesting intention movements to find a high place to roost (Olsson and Keeling, 2000).

Hens do not appear to have preferences for specific perch materials (Appleby *et al.*, 1998; Lambe and Scott, 1998), but their ability to take off and land from them appears to be affected by the perch material and degree of soiling, which determine slipperiness (Scott and MacAngus, 2004). Birds take longer to jump between perches when the distance between perches is greater (150 versus 50 cm, Scott *et al.*, 1999; 100 versus 50 cm, Taylor *et al.*, 2003 and 80 versus 60 cm, Moinard *et al.*, 2004). More clumsy and missed landings were observed when jumping at a downward angle between perches compared to jumping upward (Moinard *et al.*, 2004). Lighting levels did not affect frequency or time taken to jump between perches when intensities were equal to or greater than 1.5 (Taylor *et al.*, 2003) or 5 lux (Moinard *et al.*, 2004) but birds took longer to jump and vocalized more before jumping when light levels were under 1 lux, particularly when dark coloured perches were used (Taylor *et al.*, 2003). These factors may be important in non-cage systems where accidents during flight or when moving between perches can lead to bone breakage, particularly of the keel bone (Whitehead and Fleming, 2000),

The provision of perches has been shown to affect several behavioural, physiological and health parameters. The heterophil:lymphocyte ratio was lower in cockerels in cages with a perch, suggesting that they were stressed in the absence of a perch although tonic immobility (as a test of fearfulness) was unaffected (Campo *et al.*, 2005). In non-cage systems plumage condition was improved and frequencies of vent pecking (Wechsler and Huber-Eicher, 1998) and of aggressive pecking (Cordiner and Savory, 2001) were lower when perches at heights of at least 70 cm were provided. A number of studies have shown that provision of perches in conventional and furnished cages improves bone strength (Hughes and Appleby, 1989; Norgaard-Nielsen, 1990; Gregory *et al.*, 1991; Hughes *et al.*, 1993; Barnett *et al.*, 1997b, Barnett *et al.*, 2009; also see section on osteoporosis). Although there appears to be some potential advantages to bird welfare by the provision of a perch on bone strength, it is not necessarily accompanied by reduced bone fractures (Gregory *et al.*, 1991). Furthermore the effects of perches on non-load bearing bones are unclear and these bones may be adversely affected by, or derive no benefit from, perches. One adverse effect of perches is the deformation of the keel bone (sternum) (Appleby, 1993; Tauson and Abrahamsson, 1994; Abrahamsson *et al.*, 1996; Moe *et al.*, 2004). This defect rarely occurs in conventional cages (Abrahamsson and Tauson, 1995). Perches can also affect foot health, provide a place for parasitic red mites to live and survive, and their design and placement can increase the risk of coccidiosis from the build-up of manure under perches. The effects of perches on health and hygiene are covered in more detail in later sections.

Rearing without a perch in non-cage systems resulted in higher mortality and cloacal cannibalism (Gunnarsson *et al.*, 1999) and affected learning with mislaid eggs as a consequence (Gunnarsson *et al.*, 1999; 2000b). Other factors during rearing in non-cage systems that have effects on adult hens are exercise from rearing in aviaries improving subsequent bone strength (Michel and Huonnic, 2003) and perches reducing keel bone deformations when hens are subsequently housed in furnished cages (Moe *et al.*, 2004). Any effect of rearing with perches on the welfare of hens kept in cages as adults is largely unknown.

If a perch is present, but there is no nest there is an increased risk of cracked eggs due to hens laying their eggs from the perch (Appleby *et al.*, 1992; Glatz and Barnett, 1996). While there have been reports of increased cracked and/or dirty eggs (Ruszler and Quisenberry, 1970; Glatz and Barnett, 1996) and reduced egg mass output (Tauson, 1984) as a consequence of a perch in a cage, this appears to depend on its design and placement of the perch (Tauson, 1984; Appleby *et al.*, 1992; Duncan *et al.*, 1992; Abrahamsson and Tauson, 1993, Abrahamsson *et al.*, 1995). Broken and dirty eggs can be problem in some designs of furnished cages (Guesdon and Faure, 2004) although other studies show more acceptable figures (Appleby *et al.*, 2002; Wall and Tauson, 2002).

In summary, although there have only been a few attempts to quantify strength of perching motivation, most hens prefer to use a perch for resting, particularly at night. There has been little research focusing on any behavioural or physiological consequences of the deprivation of perching *per se*. The majority of the research on perching has been with regard to improvements in the strength of the limb bones in cages, although there is also evidence for a negative effect on keel bones when perches are provided in both cages and non-cage systems. Implications of providing perches on foot health and cage hygiene are reviewed in other sections.

Feather pecking and cannibalism

Feather pecking and cannibalism occur in every type of housing system for laying hens, but the consequences can be significantly worse in non-cage systems where the problem can spread more easily throughout the flock (Tauson, 2005). With the European Council Directive set to eliminate conventional cage systems in Europe there has been a considerable research effort devoted to understand the causes of and develop strategies for prevention of feather pecking and cannibalism. These behaviour problems are multifactorial and despite the large body of research (see recent reviews by Sedlackova *et al.*, 2004, Newberry, 2004; Rodenberg and Koene, 2004; van Krimpen *et al.*, 2005; Rodenberg *et al.*, 2008) feather pecking is still prevalent throughout the layer industry and outbreaks of cannibalism are difficult to predict and to control. Savory (1995) first distinguished the various forms of pecking that have been subsequently used in studies addressing causation and prevention; these include gentle feather pecking without removal of feathers, severe feather pecking leading to feather loss, tissue pecking directed at featherless areas and vent pecking which is directed specifically at the cloaca and the feathers around it (Rodenberg and Koene, 2004). All of these are distinct from pecking that occurs in the context of social aggression.

Current thinking is that the behavioural mechanisms underlying the various forms of feather pecking and cannibalism are different (McAdie and Keeling, 2002; Rodenberg *et al.*, 2004; Newberry *et al.*, 2007; Dixon *et al.*, 2008) although they may grade into one another. The appearance of blood or feather damage caused by severe feather pecking may lead to tissue pecking and cannibalism (Rodenberg and Koene, 2004). Feather pecking is often suggested to arise from either redirected ground pecking (Blokhuis, 1986) or dust bathing (Vestergaard and Lisborg, 1993) when birds are either reared or housed as adults without litter substrate (Huber-Eicher and Wechsler, 1997); however, this behaviour occurs even when hens are kept on litter throughout their lives (Huber-Eicher and Sebo, 2001). Vent pecking is distinct in that the key stimulus for it appears to be the exposure of the cloacal mucosa immediately after egg laying (Savory, 1995). Although the underlying causes of feather pecking and vent pecking may be different, a cross-sectional study of their prevalence in non-cage systems indicated that they share some common environmental risk factors (Pötzsch *et al.*, 2001).

There is little doubt that the welfare of victims of severe feather pecking and cannibalism is compromised. Gentle and Hunter (1990) found electroencephalographic (high frequency, low amplitude patterns), cardiovascular (increased blood pressure) and behavioural (agitation followed by immobility) responses of hens to progressive removal of feathers that are considered to be indicative of pain. Feather loss also results in increased feed intake and reduced feed efficiency due to increased heat loss (Lee *et al.*, 1983; Glatz, 2001), so that thermal comfort of birds with poor plumage is potentially compromised depending on feed quality, quantity and accessibility and hen appetite. In addition to the associated feather loss, injury and mortality, high levels of feather pecking or poor plumage condition may be associated with fearfulness measured by tonic immobility (Lee and Craig, 1991; El-lethey *et al.*, 2000) and stress as indicated by heterophil:lymphocyte ratio (El-lethey *et al.*, 2000; Campo *et al.*, 2001). While these studies provide evidence that being feather pecked causes a stress response in victims, there is also some evidence that feather pecking behaviour can be caused by factors associated with the stress response; feeding corticosterone to hens that increased concentrations in the blood resulted in significantly higher levels of feather pecking than hens in similar housing but on control diets (El-lethey *et al.*, 2001). Using technology that allowed tracking the movements of individual hens in an aviary housing 1000 birds, Friere *et al.* (2003) found that hens with poor plumage due to feather pecking had lower body weights and spent more time on the slatted, less populated areas of the house, presumably to avoid being pecked. The authors used the term 'pariah' to describe hens in non-cage systems that are repeated victims of feather pecking and consequently develop strategies to escape and hide from other birds (Friere *et al.*, 2003). Identification of 'pariahs' has been included in the welfare assessment protocol developed for hens in free-range systems by Whay *et al.* (2007) and it has also been suggested that provision of escape areas are important for protecting the welfare of victimized hens in large non-cage systems (Friere *et al.*, 2003).

The etiology of feather pecking is complex and contributing factors include nutrition and feed form, early rearing experience with regard to substrates and perches, availability of foraging material in the laying environment, light intensity and genetic predisposition (Sedlackova *et al.*, 2004, Rodenberg and Koene, 2004; van Krimpen *et al.*, 2005). In furnished cages and non-cage systems the availability and design of perches and feeding troughs, as well as litter quality can also play a role (Glatz and Barnett, 1996; Friere *et al.*, 1999; Green *et al.*, 2000; Newberry, 2004). Vent pecking and cloacal cannibalism are also affected by hormonal state with the prevalence being higher for hens with an early onset of lay (Pötzsch *et al.*, 2001; Newberry, 2004).

Van Krimpen *et al.* (2005) provided an extensive review of the literature on the role of nutrition and feeding management on feather pecking. Mineral or protein deficiencies or feeding low levels of synthetic amino acids that directly reduce plumage condition can increase the prevalence of severe feather pecking because birds are attracted to peck at feathers that are ruffled or unusual in appearance (McAdie and Keeling, 2000). The scientific literature does not support the industry view that feeding proteins of primarily vegetable origin rather than animal origin leads to increased feather pecking (van Krimpen *et al.*, 2005). Any effects of amino acid deficiency or protein source may be of particular concern in organic rearing where inclusion of some forms of nutrients or additives in the diet are restricted and beak trimming is prohibited (Kjaer and Sorensen, 2002). Reducing the energy content of the diet and increasing fibre content reduces feather pecking as birds may spend more time eating (van Krimpen *et al.*, 2005). Similarly hens fed pelleted diets are more likely to develop feather pecking than hens fed mash diets possibly because the hens fed mash diets spend more time feeding or can forage in the mash (Savory *et al.*, 1999; also see van Krimpen *et al.*, 2005), but provision of a foraging material such as straw when feeding a pelleted diet, can alleviate the problem (Aerni, *et al.*, 2000).

Feeding higher levels of insoluble fibre or roughages such as silage or carrots has been shown to increase the activity of the upper gastrointestinal tract leading to higher gizzard weight as well as reducing feather pecking and improving plumage condition (Steenfeldt *et al.*, 2007). Hens sometimes eat feathers and feather eating has been suggested to contribute to the etiology of severe feather pecking (McKeegan and Savory, 1999). Harlander-Matauschek *et al.* (2007) found that hens with a genetic predisposition for high levels of feather pecking were more attracted to access and eat feathers than low feather pecking birds. Hetland *et al.* (2005) found more feathers in the gizzards of birds fed diets low in insoluble fibre compared to those supplemented with coarse oat hulls. The function(s) of eating feathers may have to do with stimulating gizzard activity (Hetland *et al.*, 2005) since domestic fowl are unable to digest the keratin protein and presumably derive no nutritive value from feathers (McKeegan and Savory, 1999).

The relationship between provision of foraging substrates and feather pecking was discussed earlier in this review. As an alternative to foraging substrate, provision of a string enrichment device that non-beak trimmed birds could peck at significantly reduced feather pecking in floor pens and improved feather condition in conventional cages (McAdie *et al.*, 2005). The same string device also reduced injurious pecking that is usually directed at birds with experimentally trimmed or altered feathers (Jones *et al.*, 2002). Although evidence from studies of hens in commercial non-cage systems suggests that poor litter quality in the laying house does in fact increase the risk for feather pecking (Green *et al.*, 2000) the long-term effects of early access to litter on feather pecking and cannibalism in commercial flocks is less certain. A systematic review by Aerni *et al.* (2005) suggested that early access to litter (from day 1) reduced mortality but not cannibalism in aviary systems and suggested the mortality was caused by some other factors.

Although feather pecking and cannibalism can both spread throughout a flock of birds, it is still not clear whether the behaviour is socially transmitted (learned from observing other birds performing the behaviour) (McAdie and Keeling, 2002; Newberry, 2004). However, in non-cage systems a number of studies found that feather pecking and/or cannibalism increases with increasing group size (Nicol *et al.*, 1999; Bilčík and Keeling, 2000; Hetland *et al.*, 2004). While cannibalism is significantly reduced in cages compared to non-cage systems, the tendency for the behaviour to spread may not be exclusive to aviaries. Tablante *et al.* (2000) analyzed the spatial distribution of mortality from cannibalism in a commercial flock of hens in conventional cages and found there were clusters of mortality. This suggests that either birds in certain areas of the facility are experiencing similar environmental causes, or the behaviour can spread through social learning. Even if birds do not learn the behaviour from watching others, a few hens that feather peck can do more damage when in a large group (Rodenburg *et al.*, 2005). Additionally, if a hen has damaged feathers (McAdie and Keeling, 2000) or feathers that differ in colour or appearance from other hens (Bright, 2007), they attract more pecking. Therefore, reducing visual stimuli is important in controlling the behaviour and explains why feather pecking is significantly reduced at lower light levels (Kjaer and Vestergaard, 1999). Dimming the light is one of the most common means of control, and increasing the intensity of the lights during inspection has been shown to increase risk of both feather pecking and vent pecking in non-cage flocks (Pötzsch *et al.*, 2001).

Genetic selection for reduced feather pecking and increased survivability appears to be the most promising solution (Muir and Craig, 1998; Rodenberg *et al.*, 2004, 2008a; Ellen *et al.*, 2008). Although differences among strains in feather pecking, plumage condition and cannibalism have been observed for many decades, efforts to include these traits in selection studies have only been considered more recently (Kjaer and Hocking, 2004). Estimates for heritabilities for these traits vary considerably across studies (see Kjaer and Hocking, 2004) and depend on the whether plumage condition or feather pecking behaviour are used as selection criteria and the ages at which the various traits are observed. Several experimental lines of birds that differ in their tendency to perform feather pecking have been developed through individual and group selection (Kjaer and Hocking, 2004). A variety tests for behaviour traits that may predict feather pecking or cannibalism have been investigated with the goal of using them as selection criteria to reduce feather pecking in commercial strains of birds, but with little to limited success (Albentosa *et al.*, 2003; Uiotdehaag *et al.*, 2008). In a multi-strain comparison of 12 commercial layers strains and 13 unselected traditional lines, Hocking *et al.* (2004) found that although there was extensive between breed variation in both feather pecking and cannibalism, correlations betweens those two traits were low as were the correlations with other behavioural traits such as time budgets, various tests for fear responses, social behaviour and pecking at inanimate objects. The highest heritabilities and most successful attempts at eliminating feather pecking and cannibalism have been through genetic selection that considers feather pecking, cannibalism and aggressive pecking as a combined trait based on group rather than individual selection. The trait is quantified simply as survivability (or mortality) when non-beak trimmed hens are held in small groups in cages in fairly bright lighting conditions (Muir and Cheng, 2004; Ellen *et al.*, 2008). Mortality of non-beak trimmed hens in multiple bird cages was reduced though this method of group selection from 68% to 8% in six generations, with corresponding significant increases in eggs per hen housed (Muir and Cheng, 2004) and the authors suggested that their selection scheme could eliminate the need for beak trimming. Different lines of birds selected for either high or low feather pecking or survivability also show striking differences in other aspects of their behaviour, adrenal function and other neurobiological responses to stress (Korte *et al.*, 1997; van Hierden *et al.*, 2002; Rodenburg *et al.*, 2002; Cheng and Muir, 2004) and this is an area of research attracting more attention.

Control of cannibalism due to feather pecking is often regarded one of the major advantages of conventional cages for laying hen welfare (Tauson, 2005), especially when the birds are not beak trimmed. Although plumage condition is often found to be worse in cages (Barnett *et al.* 1997a; Michel and Huonnic, 2003), the range and variation in mortality due to the various forms of cannibalism are considerably higher in non-cage systems (see EFSA, 2005). Medium and large furnished cages as well as non-cage systems are considered to put birds at considerable risk of cannibalism compared to conventional and small furnished cages when birds are not beak trimmed (Blokhuis *et al.*, 2007). More recently, a 5-year retrospective study of causes of mortality in hens submitted for necropsy to the National Veterinary Institute in Sweden (where beak trimming is prohibited) reported a significantly higher occurrence of mortality due to cannibalism in indoor non-cage and free range systems compared to conventional and furnished cage systems (Fossum *et al.*, 2009). Aerni *et al.* (2005), suggested a contrary view on the effect of housing system based on a systematic review of 14 studies, which compared productivity measures, cannibalism and mortality in conventional cage versus non-cage systems. The authors also used data from 16 studies to analyze for the amount of variation in the data set explained by beak trimming and rearing condition. Their results indicated that housing system affected egg mass, food conversion and food consumption but not cannibalism or mortality, whereas beak trimming significantly affected cannibalism and strain accounted for variation in both cannibalism and mortality. Beak trimming is currently the best available prevention for feather pecking and cannibalism, but continues to raise both welfare and ethical concerns.

In summary, feather pecking and cannibalism are multi-factorial problems that can severely compromise the welfare of recipient laying hens. Feather pecking is considered to be redirected foraging, and although providing mash feed and foraging substrates do reduce feather pecking, the behaviour can occur even when birds are reared and housed on litter throughout their lives. The consequences of feather pecking and cannibalism are most severe when hens are held in large groups such as in non-cage systems and when they are not beak-trimmed. Apart from beak trimming, which has welfare implications of its own, genetic selection shows the most promise for eliminating the problem.

Osteoporosis and broken bones

Osteoporosis is a widespread problem for laying hens in all types of housing systems. There have been several reviews examining the mechanisms of bone formation as well as various factors responsible for osteoporosis (Newman and Leeson, 1997; Knowles and Wilkins, 1998; Whitehead and Fleming, 2000; Whitehead, 2004). Osteoporosis involves the progressive loss of structural bone resulting from a change in the mechanisms of bone formation and turnover that begins at sexual maturity and continues throughout the laying period (Whitehead and Fleming, 2000; Whitehead, 2004). Prior to lay, the majority of bone tissue formation and resorption is structural in nature (i.e. trabecular and cortical bone) but at sexual maturity the hen begins producing medullary bone under the influence of oestrogen. Medullary bone serves as a reservoir for the calcium needed for daily eggshell formation but is fundamentally weaker than structural bone (Fleming *et al.*, 1998a). Medullary bone is produced at the expense of structural bone, and over time, the amount of structural bone is diminished. The process is reversed when a hen goes out of lay and structural bone regenerates with a loss of medullary bone. This cycle of loss and regeneration in structural bone is normal for birds laying in clutches and raising young so that in nature, a hen would be able to maintain good bone quality over her lifetime (Whitehead, 2004). However, selection for continuous production and the high rates of lay in the modern hen results in severe losses in structural bone over the production period making bones increasingly more fragile. The main factors that influence the severity of osteoporosis are opportunities for load bearing exercise and genetics, although nutrition plays a minor role (Fleming *et al.*, 2006).

Housing has a significant effect on the severity of osteoporosis. Lack of physical activity contributes to the development of fragile bones in conventional cages (Whitehead and Fleming, 2000). Increased space in cages can improve the strength of some bones, possibly through increased opportunities for wing flapping. Barnett *et al.* (2009) reported an experiment that examined the effects of increasing space per bird (8 birds in single and double-width cages that provide either 750 or 1500 cm^2/bird) and the effects of group size (8 and 16 birds in double-width cages with a space allowance of 750 cm^2/bird). They found an effect of space in that there was an increase in bone strength of the femur, tibia and coracoid in 8 or 16 bird double cages compared to 8 bird single cages, although the increase was only statistically significant for the coracoid. Moinard *et al.* (1998) found no difference in tibial breaking strength in hens from cages differing in floor space (450, 600 or 800 cm^2) and/or height (40 or 60 cm), however, they did find higher humeral breaking strength in the 60 cm high cage. The incidence of broken wings was significantly lower at the higher cage height although the authors contributed at least part of this difference to the larger cage openings, which may have resulted in fewer injuries during depopulation. There is substantial evidence that provision of perches in conventional and furnished cages improves strength of the leg bones (Hughes and Appleby, 1989; Nörgaard-Nielsen, 1990; Gregory *et al.*, 1991; Hughes *et al.*, 1993; Barnett *et al.*, 1997b).

The greatest improvements in bone strength are realized when hens have opportunities for a wider variety of load bearing activities. Barnett *et al.* (1997b) found that bone strength was significantly higher for the femur, humerus and tibia in floor pens with perches compared to conventional cages with and without perches, while inclusion of a perch in conventional cages only increased the strength of the femur. Fleming *et al.* (1994, as reported in Whitehead and Fleming, 2000) showed improvements in various bone measurements in non-cage systems compared to conventional cages with differences being more pronounced in a multi-tiered systems compared to a system with litter and wire floors and relatively low perches. The authors concluded that opportunity for flight was an important factor, particularly for improving humeral strength. Leyendecker *et al.* (2005) found increased humeral strength in furnished cages compared to conventional cages while humeral and tibial breaking strength was higher in an aviary compared to both types of caging systems. More recently, Jendral *et al.* (2008) measured bone breaking strength of the femur, humerus and tibia in hens that had been kept in conventional cages, modified cages (addition of nest box and perch), colony cages (26 birds/cage) furnished with a nest box and a perch with or without access to an elevated area for dust bathing. Birds in all treatments had 450 cm^2 of floor space per hen not including nest box area. Hens in conventional cages had significantly lower breaking strength in the femur and tibia compared to all other treatments, while breaking strength was highest for all three bones in the colony cages with access to the elevated dust bath. These data suggest that among cage systems those that provide the greatest opportunities for load bearing activities promote the strongest bones.

There is evidence that bone strength can improve within a relatively short time after moving hens to an environment that allows for more exercise. Newman and Leeson (1998) found that tibial strength of 69-week-old hens that had been housed in a multi-tiered aviary system was significantly higher than that of hens that had been housed in conventional cages. When hens were moved from the cages to the aviary at 69 weeks of age, tibial strength increased significantly and after 20 days in the aviary was equal to that of hens who had been housed in the aviary for the entire production period. However, in this study it was not recorded whether there was any pause in egg laying following the move; this would have contributed to the observed bone regeneration.

The effects of deficiencies in calcium, phosphorus and Vitamin D on the severity of osteoporosis have been reviewed (Newman and Leeson, 1997; Webster, 2004). Overall, nutritional strategies aimed at eliminating osteoporosis during the laying period are largely ineffective (Newman and Leeson, 1997; Rennie *et al.*, 1997; Fleming *et al.*, 1998b; Fleming *et al.*, 2006). Feeding calcium in particulate form (i.e. oyster shell) rather than in a ground form can alleviate some of the characteristics of osteoporosis as it slows release and absorption making the calcium more readily available during the night when eggshell formation occurs, thus reducing the need for mobilization of bone calcium (Fleming *et al.*, 2006). Feed withdrawal in aged hens for the purposes of induced molt or prior to depopulation of a flock results in a rapid deterioration of bone strength making the spent layer even more susceptible to broken bones (Newman and Leeson, 1999).

The major welfare implication of osteoporosis in the laying hen is susceptibility to bone fracture that can occur during production or during handling at depopulation (Webster, 2004). Although the behavioural and physiological responses to bone fracture have not been specifically investigated in domestic fowl, broken bones are likely to be painful at the time of the break and during the healing process (Gentle and Wilson, 2004). There is substantial evidence that both prevalence and timing of bone fractures are significantly affected by housing system (Knowles and Wilkins, 1998; Gregory *et al.*, 1990; Sandilands *et al.*, 2008). An early survey on hens from conventional cages found 29% of hens had fresh breaks and 5% had old breaks at the time of slaughter (Gregory and Wilkins, 1989). Some of the problems of broken bones during handling and transport in hens kept in cages occur as a result of cage design and certainly improved door design (e.g. S-shaped full width doors) as described in Tauson (1985) and Elson (1990) should improve access and reduce the risk of bone breakages when removing birds from cages. Full width doors are recommended in many welfare codes of practice (Primary Industries Standing Committee, 2002).

Although birds from non-cage systems have stronger bones and experience fewer breaks during depopulation and slaughter, they have a much higher prevalence of old breaks compared to caged hens (Gregory *et al.*, 1990; Knowles and Wilkins, 1998). More recent estimates of old breaks of the keel and furculum ranged from 50 to 78 % of birds sampled from free range flocks and from 62 to 72% of hens sampled from flocks housed indoors on litter and wire floor housing (Wilkins *et al.*, 2004). In an extensive study involving 6 replications of 6 different combinations of stocking density and flock size in single-tiered aviaries, Nicol *et al.* (2006) found that 60% of hens sampled had evidence of fractures by the end of lay; the incidence was not affected by stocking density or flock size. A recent report by Sandilands *et al.* (2008) comparing bone breakage at depopulation in 18 commercial flocks that were housed in conventional cage, furnished cage, indoor non-cage and free range systems showed new breaks, primarily of the wings, to be highest in conventional cages (24%) while old breaks, primarily of the keel, to be more prevalent in non-cage systems (33, 54 and 52% for furnished cage, free range and non-cage barn flocks, respectively). A comparison of 6 commercial flocks housed in furnished cages, 3 flocks in single-tiered and 4 flocks of multi-tiered non-cage systems indicated that of the 30 birds sampled from each flock, 62, 82 and 97 %, respectively, had keel bone fractures at 60 weeks of age (Rodenburg *et al.*, 2008b). The prevalence of old breaks found in non-cage systems is thought to be due to trauma that occurs from accidents during flight, falls or being pushed off perches (Whitehead and Fleming, 2000). The histopathology of keel bone deformities (a condition commonly reported for housing systems furnished with perches) indicates that the deformities are a result of trauma rather than a developmental problem (Fleming *et al.*, 2004).

There is considerable genetic variation in the bone characteristics of laying hens with commercial breeds generally having significantly weaker bones than traditional strains (Hocking *et al.*, 2003). Differences in bone strength between specific strains of hen have been described (Leyendecker *et al.*, 2002 as cited in EFSA, 2005); Lohmann Traditional showed higher tibia and humerus strength than Lohmann Selected hens. Riczu *et al.* (2004) found bone-breaking strength to be significantly greater in both the radius and humerus of a brown-egg (Shaver 579) strain compared to a white-egg strain (Shaver 2000) at 66 weeks of age. Silversides *et al.* (2006) found strain differences in trabecular and cortical densities as well as breaking strength of the humerus, with an unselected strain of Brown Leghorn having stronger bones than either a commercial strain of brown (ISA-Brown) or white (Babcock B300) egg layers. When the caged hens were processed at 77 weeks of age, Budgell and Silversides (2004) compared numbers of hens with old breaks, breaks that occurred during transport and breaks that occurred during processing from a sample of approximately 60 hens per strain. Old breaks were identified in 11.1 and 11.7% and transport breaks in 7.9 and 10% of hens in the two commercial lines, respectively, compared with 0.0 and 3.5% hens with old and transport related breaks, respectively in the heritage line. Hens in all three lines had breaks during processing. Relatively recent research has shown that bone strength is heritable (Bishop *et al.*, 2000) and that divergent selection for skeletal improvement is extremely effective at both improving resistance to osteoporosis (Fleming *et al.*, 2006) and in reducing incidence of keel bone deformities (Fleming *et al.*, 2004). Thus, genetic improvements in bone strength, independently of changes to housing system, would be expected to reduce bone breakages in all types of housing (Whitehead *et al.*, 2006).

In summary, osteoporosis is a condition mainly caused by selection for high productivity in the modern laying hen although some aspects of nutrition and environment can contribute to the problem. In conventional cages, the lack of opportunities for load bearing exercise contribute to bone weakness, but bone breaks in cages mainly occur at the end of the production cycle when hens are removed from cages and handled for slaughter. Although hens in non-cage systems, and especially multi-tiered systems, have stronger bones, they are still highly susceptible to bone breaks. A high proportion of hens in non-cage systems have been found to have evidence of broken bones occurring sometime throughout the laying cycle, presumably from trauma during flight and locomotion in those environments. Increasing the strength of hens' bones, primarily through genetic selection, is necessary to improve the welfare of hens in all types of housing systems.

Health and hygiene

In evaluating the welfare issues for laying hens, consideration for aspects of physical comfort and bird health are important. For the laying hen, major issues include air quality in hen houses, infectious disease and parasites, and foot health. In the following sections we review how various aspects of housing systems for hens and how specific management practices within those systems can affect these factors.

Air Quality

Poor air quality can compromise welfare by causing irritation and discomfort, and reducing respiratory health. Although few studies have directly assessed the effects of air quality on the respiratory health of laying hens, studies on poultry workers indicate that exposure to both dust and ammonia has a synergistic effect on respiratory dysfunction (Donham *et al.*, 2002). Levels of dust, airborne microorganisms and endotoxins are affected by environmental factors, including litter and manure handling (Takai *et al.*, 1998, Seedorf *et al.*, 1998). The use of litter has been linked to higher dust concentrations in the air (Mårtensson and Pehrson, 1997; Ellen *et al.*, 2000). Large quantities of litter, in conjunction with high levels of bird movement in non-cage systems, are potential risk factors for a higher prevalence of bacteria, fungi and dust relative to caged-layer systems (Mårtensson and Pehrson, 1997; Seedorf *et al.*, 1998, Larsson *et al.*, 1999; Rodenburg *et al.*, 2005). Larsson *et al.* (1999) found that higher dust levels were linked to fresh, rather than old, litter, and the authors suggested that this was likely a result of the higher moisture content in old litter, which prevents dust particles from aerosolizing. However, in their experiment, fresh litter was used with younger, more active hens, resulting in greater agitation of the litter; therefore, age and/or breed likely also has an effect on the dust concentration in housing systems in which litter is used.

Dust and endotoxin levels are reported to be 2-5 times higher in non-cage systems with loose litter than in conventional or furnished cages (Takai *et al.*, 1998; Seedorf *et al.*, 1998; Larsson *et al.*, 1999). The inhalable dust concentration in aviaries has been found to range from 2.4 - 12 mg/m^3 and tends to vary over the day (Wachenfelt, 1999, as reported by Ellen *et al.*, 2000). For example, Takai *et al.* (1998) reported that mean inhalable dust concentrations in deep-litter non-cage systems were 7.33 mg/m^3 and 2.82 mg/m^3 during the day and night, respectively, whereas those in conventional cages were 1.51 mg/m^3 and 0.86 mg/m^3. It has been suggested that dust bathing and scratching activities are responsible for the diurnal variation in dust concentrations in both systems (Groot Koerkamp and Bleijenberg, 1998). Michel and Huonnic (2003) reported that histological examination of the lungs of hens revealed more severe lesions characteristic of chronic bronchitis in hens that were housed in aviaries with maximum dust concentrations of 31.6 mg/m^3 compared to hens from caged layer facilities with maximum dust concentrations of 2.3 mg/m^3. Rodenburg *et al.* (2008b) measured higher levels of inhalable and respirable dust concentrations as well as total numbers of aerobic bacteria in the air and on eggshells in commercial flocks in single and multi-tiered non-cage systems compared to flocks in furnished cages. Mortality was over twice as high in the non-cage flocks and causes included health problems such as *E. coli* and infectious bronchitis. Humans exposed to loose litter systems have shown a greater inflammatory response in the bronchioles than those exposed to cage systems; however, the causative agent in dust for this reaction is unknown (Larsson *et al.*, 1999).

Ammonia can affect laying hen welfare in several ways. Although it has been shown to reduce the survival rates of common pathogens in dry manure (Himathongkham and Riemann, 1999), high concentrations of ammonia are believed to promote the emergence of clinical signs in hens that have subclinical infections (Murakami *et al.*, 2002), and are known to cause air sac lesions, kerato-conjunctivitis, and reduced feed intake resulting in weight loss (see review by Kristensen and Wathes, 2000). Laying hens might also find some concentrations of aerial ammonia aversive.

Several studies have demonstrated the ability of hens to detect and discriminate among different concentrations of ammonia. McKeegan *et al.* (2002) measured electrical activity of olfactory bulb neurons in laying hens exposed to different concentrations of ammonia and found a median response threshold of 3.5 ppm. McKeegan (2004) also demonstrated concentration-response curves to ammonia by the trigeminal nerves in the nasal mucosa and palette of laying hens; this is the common chemical sense outside of the olfactory system that is capable of responding to noxious substances in the environment and often results in avoidance behaviour. In follow-up to the neurophysiological studies, McKeegan *et al.* (2005) measured the behavioural responses of hens to brief (7s) pulses of varying concentrations of ammonia (5-100 ppm). The hens oriented to the source of the odor at 10 ppm and showed blinking and eye shutting in response to 20 ppm.

When given a choice to move freely among compartments with different ammonia concentrations hens were observed to spend 42, 29 and 29% of the time in 0, 25 and 45 ppm, respectively, and they foraged, rested and preened at a greater frequency in fresh air environments than in ammonia-polluted ones (Kristensen *et al.*, 2000). Although frequency of visits lasting < 75 minutes in each of the compartments was similar; a higher proportion of visits lasting > 75 minutes occurred in the fresh air compartment (Kristensen *et al.*, 2000). Preference studies using growing female broiler chickens at lower concentrations indicated that the threshold for avoidance is approximately 12 ppm of ammonia (Jones *et al.*, 2005). The most commonly recommended maximum concentration for poultry houses is 25 ppm, which is based on human safety guidelines rather than any measures of poultry welfare.

Several management factors can affect the concentration of ammonia in the air. Regardless of housing system, manure storage has a large influence on the ammonia concentration. Ammonia levels were observed to increase 30 – 40% daily between manure-belt cleanings in conventional cages (Liang *et al.*, 2005; Fabbri *et al.*, 2007) and 20% non-cage multi-tier systems (Groot Koerkamp and Bleijenberg, 1998).

Litter management has also been linked to ammonia concentration. In housing systems with long-term storage of litter inside the buildings, there are high concentrations of ammonia, (Mårtensson, 1995). A survey of concentrations of ammonia in livestock houses in northern Europe found that ammonia concentrations in layer houses often exceeded 25 ppm and this was more prevalent in non-cage and deep litter systems than in conventional cage systems (Groot Koerkamp, *et al.*, 1998).

Season also plays a role in exposure to ammonia, particularly in temperate climates where mechanical ventilation is used. To reserve heat in the barn in the winter, the ventilation rate is reduced, causing an increase in ammonia concentration in the air. In the spring and summer, when air has high absolute moisture content, an increase in respiratory rate results in increased inspiration of ammonia as well as dust particles (Kristensen and Wathes, 2000).

In summary, aerial concentrations of dust, microbes and ammonia are substantially greater in non-cage systems than in conventional or furnished cages because they are easier to control in the latter two systems (Ellen *et al.*, 2000; Tauson, 2005). Hens appear to be able to detect and prefer fresh air to higher levels of ammonia, although the time they have been observed to spend at concentrations of 25 and 45 ppm suggest that these concentrations are not highly aversive to them. Elevated concentrations of dust and ammonia may have detrimental effects on health.

Infectious Diseases

Infectious diseases can occur in any housing system; however, some systems increase the risk for specific diseases to develop and spread (EFSA, 2005). One of the most important potential risks is related to biosecurity, that is, the level of hygiene and the number of birds kept in close contact. Therefore, the risk of disease is likely very sensitive to the type of housing system, for example, the presence of litter in non-cage systems or access to free range areas, in comparison to small groups of hens housed in cages (Jansson, 2001 as cited in EFSA, 2005). The lack of control over biosecurity in some alternative systems might play an important role in the development of infectious diseases.

There have been several reports in which non-cage systems were widely introduced in an area and where the prevalence of bacterial infections such as erysipelas, *E. coli* and pasteurellosis show a marked increase in floor-kept hens compared to caged hens (Häne *et al.*, 2000; Hafez, 2001; Hafez *et al.*, 2001).

Approximately 80% of the confirmed outbreaks of fowl cholera (*Pasteuralla multocida*) in domestic poultry in Denmark occurred in free-range flocks (Christensen *et al.*, 1999), which suggests a significant risk of introduction of this pathogen into free-range poultry from the avifauna or indirectly by wild carnivores (Eigaard *et al.*, 2006). The genetic stability of outbreak clones of *P. multocida* that caused high mortality on two Danish farms further emphasizes the increased risk of infectious diseases associated with free-range access (Eigaard *et al.*, 2006). The prevalence of *Clostridium perfringens*, the causative agent of necrotic enteritis, is higher in free-range systems than in conventional cage systems (Omeira *et al.*, 2006) because of the ability of the spores to survive in litter and soil. It has been suggested that pecking the soil plays a role in its persistence and transmission (Omeira *et al.*, 2006). On the other hand, intensively-managed layer houses had more *Staphylococcus* spp. in the litter compared to free-range systems (Omeira *et al.*, 2006). The authors suggested that this is due to the greater frequency with which free-range systems replenish their litter.

In furnished cages, the occurrence of infectious diseases has been shown to be similar to that in conventional cage systems (Tauson and Holm 2002 and 2003; Van Emous *et al.*, 2003 as cited in EFSA, 2005), and in their review, Rodenburg *et al.* (2005) concluded that there was no significant difference in the level of bacterial contamination in the environment of conventional and furnished cages. A recent 5-year retrospective study of causes of mortality in hens submitted for necropsy to the National Veterinary Institute in Sweden reported a significantly higher occurrence of parasitic and bacterial diseases in indoor non-cage and free range systems compared to cage systems (conventional and furnished combined); the occurrence of viral disease was significantly higher in indoor non-cage systems than in either free range or cage systems (Fossum *et al.*, 2009).

Although *Salmonella* is predominantly a public health issue, host-adapted serovars (e.g. *S. pullorum* and *S. gallinarum*) exist. Host-adapted serovars can cause severe illness in infected flocks, especially in young hens. In studies that have isolated *Salmonella* before and after depopulation and cleaning, free-range farms had a lower prevalence of *Salmonella* than cage systems (Davies and Breslin, 2003; Wales *et al.*, 2007). The higher prevalence in cage systems is believed to be the result of ineffective disinfection of the cages (Davies and Breslin, 2003, Namata *et al.*, 2008). In non-cage systems, *Salmonella* was frequently isolated from the nest boxes, manure belts, bulk feces, drinkers and dust. In free-range systems, nest boxes, slats, and perches had the highest prevalence of *Salmonella* (Davies and Breslin, 2001). In general, the major factors responsible for the prevalence of *Salmonella* contamination of the housing system are the quality of cleaning and disinfecting between flocks and the presence of rodent manure (Davies and Breslin, 2003, Wales *et al.,* 2007), the age of the flock (Wales *et al.,* 2007), and high flock densities (Davies and Breslin, 2003).

It is recognized that there are greater concentrations of airborne microorganisms in non-cage systems (Seedorf *et al.,* 1998). Aerobic, mesophilic bacteria are found in the air at a higher concentration in aviaries than in conventional cage systems, leading to increased egg contamination in the former housing system (Protais *et al.,* 2003a). Eggs laid on slats or on the floor had the greatest contamination with aerobic, mesophilic bacteria (Protais *et al.,* 2003b). No statistically significant difference was observed between conventional and furnished houses with respect to bacterial eggshell contamination with aerobic or gram-negative flora (de Reu *et al.,* 2005). Further, the use of artificial turf in furnished cages did not increase bacterial eggshell contamination relative to wire-floored cages (Tauson, 2002, de Reu *et al.,* 2005).

In summary, there is an increased risk of infectious diseases in free range systems and in some non-cage cage systems compared to conventional and furnished cages because biosecurity and hygiene are more difficult to maintain in those systems. However, disease prevalence in all systems depends on cleaning and sanitation in between flocks, and this can also be a problem in cage systems where disinfection of cage surfaces can be ineffective. There appear to be few differences in risk of infectious disease or eggshell contamination between conventional and furnished cages.

Parasitic Infections

The most common endo- and ecto-parasites of laying hens are coccidia (*Eimeria* spp.), roundworms (*Ascaridia galli* and *Capillaria* spp.), northern fowl mites (*Ornithonyssus sylvarium*) and red mites (*Dermanyssus gallinae*). Parasites act as vectors of disease, are a nuisance for the hens (Knierim, 2006), and in severe infestations, can cause death (Lundén *et al.,* 2000, Chadfield *et al.,* 2001). *Ascaridia galli* has been identified as a vector of *Salmonella enterica* (Chadfield *et al.,* 2001), and infection with roundworms results in decreased locomotory activity in addition to higher feed intake (Gauly *et al.,* 2007). Red mites have been reported as potential vectors of the bacterium *Erysipelothrix rhusiopathie* in laying hens, the causative agent of erysipelas (Chirico *et al.* 2003). Coccidial infections have been linked to the development of necrotic enteritis (Broussard *et al.,* 1986).

The feeding activity of red mites at night creates skin lesions (Axtell, 1999); chronic infestation leads to anemia, and in severe cases, it can result in death (Hoglund *et al.,* 1995). Non-cage systems have the highest prevalence of red mite infestations (Pennycott and Steel, 2001; Fiddes *et al.,* 2005). In 1994, a Swedish survey to determine the prevalence of red mites found that 21% of non-cage floor systems were infested (Hoglund *et al.,* 1995). In Denmark, the prevalence of red mites was 64% in free-range systems and 42% in deep-litter non-cage systems (Permin *et al.,* 1999). Van Emous and Ficks-van Niekerk (2003 as cited in EFSA, 2005) reported that 100% of 25 commercial free-range flocks in the Netherlands had red mites present to varying degrees. In a survey of 29 farms in Northern England, the population of nymph and adult mites was significantly higher in free-range systems than other non-cage and cage systems (Guy *et al.,* 2004). In Switzerland, 77% of farmers identified red mites at their farms. From those flocks, 50% also had worm eggs in their droppings (Häne *et al.,* 2000). With respect to conventional cages, the prevalence of red mites has been reported as 4% (Sweden; Hoglund *et al.,* 1995) and 5% (Denmark; Permin *et al.,* 1999).

Coccidial oocysts can survive in soil and can be transmitted by dust and vectors, such as flies and darkling beetles (Thamsborg *et al.,* 1999). Flocks with access to a free-range area have a relatively high prevalence of coccidial oocysts in their faecal matter (Häne *et al.,* 2000). Seventy-three percent of flocks that had access to a free-range area had *Eimeria* spp. compared to 43% of flocks without free-range access (Häne *et al.,* 2000). Furnished cages have also been known to have outbreaks of red mites and coccidia (Abrahamsson and Tauson, 1998; Appleby, 1998b).

A large Danish study on the occurrence of worm infestations showed that hens in conventional cage systems had very low (5%) levels of worms compared to hens housed on the floor (> 70%) (Permin *et al.,* 2002, as cited in EFSA, 2005). This trend was apparent whether or not the floor-reared hens had access to a free-range area, although outdoor access poses a higher risk (Jansson, 2001 as cited in EFSA, 2005; Permin *et al.,* 2002 as cited in EFSA, 2005). For example, Permin *et al.* (2002) reported the occurrence of *Ascaridia galli* in organic layers, single-level non-cage systems and cage systems as 72%, 20% and 4%, respectively; for *Capillaria obsignata*, the occurrence was 52%, 51% and 0%, respectively. In the majority of instances in which these diseases have occurred, mortality rates have risen to levels high enough to seriously compromise welfare.

Esquenet *et al.* (2003) reported an outbreak of histomoniasis (*Histomonas meleagridis,* a protozoan parasite) and spirochaetosis (*Brachyspira* spp., a spirochaete bacterium) in a free-range layer flock in Belgium that led to increased mortality and decreased egg production. The nature of the observed clinical signs and lesions suggested a major role of *Histomonas* in the disease process. *Histomonas* is transmitted horizontally, especially through intermediate hosts such as the intestinal nematode *Heterakis gallinae* and the earthworm (Esquenet *et al.,* 2003). In Europe, severe outbreaks of histomoniasis in layer flocks have not been reported for several decades, because of preventive and curative treatments with effective drugs as well as the indoor housing of hens in cages. Histomoniasis has traditionally been more important in backyard layer flocks than commercial flocks, because conventional cage systems inhibit the rapid spread of the parasite. Free-range systems might promote the re-emergence of other infectious diseases that have almost disappeared in conventional cage systems (Esquenet *et al.,* 2003), especially those that are spread through faecal excretion and/or are soil-related (Hafez *et al.,* 2001).

The physical complexity of the housing system is a major factor in the persistence of parasitic infections. The high prevalence of parasitic infections in non-cage systems is attributed to suitable hiding places, such as beneath troughs, under rods and slats, in nest boxes and in cracks and crevices in the house walls (Hoglund *et al.,* 1995; Chauve, 1998; Chirico and Tauson, 2002, Fiddes *et al.,* 2005). Red mites are very common in floor systems, especially in deep litter and slatted floors (Hoglund *et al.,* 1995). In designs that do not contain a wire floor, red mites can be found under loose clods of manure (Arends, 1997). Red mites are rare in large commercial conventional cage operations (Axtell, 1999), and if present, they are generally hidden beneath the egg conveyor belts and cage supports (Chauve, 1998). However, in Europe, due to new restrictions on the use of chemicals that leave residuals, the prevalence is likely to increase (EFSA, 2005). In commercial conventional cage systems, the northern fowl mite is the most prevalent ecto-parasite (Axtell, 1999). Modes of transmission are restocking houses with infested pullets, the presence of wild birds, and equipment, boots and clothing (Arends 1997; Axtell 1999). With low-level infestations, northern fowl mites cause mild irritation. Severe infestations can cause scabbing and cracking of the skin around the vent, and anaemia and reduced egg production (Arends, 1997).

The design of furnished cages and the use of perches have been shown to influence the risk of parasitic infections. Cages can act as a barrier for the faecal-oral transmission of parasites (Shimmura *et al.*, 2007b). However, if the cage is multi-leveled with wire-mesh floors, droppings can fall onto the hens situated on the lower levels, facilitating the faecal-oral transmission of endo-parasites (Appleby and Hughes, 1995). Similarly, if cages are stacked in tiers, faecal matter can contaminate the feed troughs of cages below (Shimmura *et al.*, 2007b). A complex cage design also makes disinfection difficult and creates numerous suitable hiding places for parasites (Chauve, 1998, Fiddes *et al.*, 2005). The area underneath or behind a perch, where hens cannot access, can build-up with faecal matter, which harbours parasitic oocysts, increases ammonia levels and creates an unhygienic environment (Appleby, 1998b). Wire floors in single-level cages prevent the spread of oocysts that are transmitted via the faecal-oral route, because hens stamp the feces through the wires, rather than letting it accumulate on the cage floor.

In summary, the prevalence of parasites in any housing system is dependent on the presence of a hospitable environment, as well as the presence of hiding spots. Non-cage systems, especially those with an outdoor component have the highest prevalence of parasites, due to the presence of soil. Hens housed in non-cage systems with litter or an outdoor component, are also more susceptible to endo-parasitic infections than hens in both conventional and furnished cage systems (Tauson, 2005). The presence of litter and the outdoor environment makes management of the environment difficult, resulting in greater risk of unhygienic conditions. Furnished cages with a complex design have more areas for parasites to hide. Further, the presence of perches is a factor in parasite prevalence, because of the potential build-up of contaminated faeces located beneath the perch.

Foot Health

Although foot lesions have not been linked to decreased production in laying hens, the severe forms of plantar foot lesions, hyperkeratosis and bumblefoot (pododermatitis) are considered to be painful (Tauson, 1980). Hyperkeratosis is a thickening of the skin that results from prolonged and intensive compression load on the foot pad, and increases the risk of developing a secondary bacterial infection (Tauson and Abrahamsson, 1994; Weitzenburger *et al.*, 2006). Compression load can be caused by perch use or by standing on wire floor. Bumblefoot is the swelling and inflammation of the subcutaneous tissues of the foot and is associated with bacterial infection (Weitzenburger *et al*, 2006); common sequalae include tendonitis, septic arthritis, and osteomyelitis.

Layer strain influences the severity (Abrahamsson *et al.*, 1996) and prevalence (Weitzenburger *et al.*, 2006) of foot lesions. In their investigation of the health and behaviour of 4 hybrids of hens housed in a variety of conventional and furnished cages, Abrahamsson *et al.* (1996) found that on a scale of 1 (worst) to 4 (best condition), Lohmann Selected Leghorns (LSL) had a significantly lower score (3.82) for bumblefoot than ISA Browns (3.93), whereas ISA Browns had a significantly lower score (3.89) for toe pad hyperkeratosis than LSL hybrids (3.96).

Higher stocking density is associated with a greater prevalence of foot lesions in conventional and furnished caged layers (Tauson and Abrahamsson, 1994; Appleby *et al.*, 2002). Higher density results in less movement and prolonged immobility, and increased weight placed on the layers' feet. Appleby *et al.* (2002) found that a stocking density of 5 hens or greater in furnished cages resulted in reduced foot health, although the difference was slight when compared to conventional cages or densities of fewer than 5 hens. The authors noted that their results might have been confounded by several variables, such as total area (including nest box space), feeder and perch space per bird, and that their results should not be interpreted as causal.

Hyperkeratosis in conventional cages is generally in the form of mild lesions on the distal toe pads (Abrahamsson and Tauson, 1993; Appleby, 1998b). Weitzenburger *et al.* (2006) considered hyperkeratosis to result from increased mechanical load from perching and grasping the wire floor. Tauson (1980) found that foot health improved in well-galvanized wire floor cages compared to those of poor-galvanized wire. Plastic floor cages produced similar foot conditions to those of well-galvanized wire, and Tauson (1998) suggested that some types of plastic might provide more support and insulation due to their solid composition. Additionally, a gentle slope has been shown to decrease the prevalence of hyperkeratosis (Tauson, 1980).

Prolonged perch use is a known risk factor for the development of hyperkeratosis. The material and shape of the perch, as well as the arrangement of the perches, have an impact on foot health (Glatz and Barnett, 1996; Wall and Tauson, 2007). Duncan *et al.* (1992) reported that hens preferred using rectangular perches to circular ones. Rectangular perches tend to be better for foot health than circular ones; however, circular or rectangular cross-sections that are too narrow result in instability while perching (Duncan *et al.,* 1992; Glatz and Barnett, 1996). More recent research has shown that round wooden perches with a flat top are better than traditional round perches for hens' foot health, and that covering perches with rubber or mesh reduces the compression load on the feet (Weitzenburger *et al.,* 2006).

The incidence of bumblefoot varies both within and across housing systems, predominantly due to moisture in faeces. Wang *et al.* (1998) showed a three-fold increase in floor systems with moisture on the perches or in the litter compared to floor systems where these areas were dry and also found that wet litter had a greater influence on the development of foot lesions than perch use did. Wet perches and temperatures > 20ºC, were associated with a higher prevalence of inflammation of the foot pad than were dry perches. Weitzenburger *et al.* (2006) suggested that secondary lesions on foot pads are due to the infiltration of micro lesions by moisture and faecal matter. Tauson and Holm (2002) found the incidence of bumblefoot was 3-4 times higher in non-cage systems than in furnished cages, where the incidence was less than 5 %. Bumblefoot is relatively rare in conventional cages (Abrahamsson *et al.*, 1996).

The act of walking in the cage keeps the wire floor clean from faecal matter. However, in furnished cages the location of the perch may be important because the area underneath can be relatively unhygienic due to the build-up of droppings. This build-up can decrease foot hygiene (Abrahamsson and Tauson, 1993, Abrahamsson, *et al.*, 1996), and result in bumblefoot (Weitzenburger *et al.*, 2006). Appleby *et al.* (2002) reported that perches located at the rear of the cage were especially associated with a build-up of faecal matter, although previous research by Duncan *et al.* (1992), in which layers housed in cages with a rear perch had the least amount of foot damage compared to hens in cages with either a front perch or both front and rear perches.

In summary, perch use, wet litter, layer strain, wire flooring and floor slope can all affect the development of foot lesions in different ways. Current research suggests that ideally, perches should have a flat surface on the top, be covered with rubber or mesh to reduce compression load, and have a smooth rather than an abrasive texture. The ideal location of the perch within the cage has yet to be determined, and sanitation must be taken into consideration. Wire flooring should be made of well-galvanized wire or plastic and have a gentle slope. Non-cage systems with wet litter have the highest prevalence of bumblefoot relative to all other housing systems.

Conclusions on welfare issues in laying hen production

This review of the literature shows that many factors may affect the welfare of commercial laying hens housed in cage and non-cage systems. The key welfare issues were identified and described in detail, and relate to the following aspects of hen welfare: space allowance, group size and stocking density; behaviour patterns constrained by conventional cages (nesting, dustbathing, foraging, perching); feather pecking and cannibalism; osteoporosis and broken bones, and health and hygiene (e.g. air quality, infectious disease, parasitic infections and foot health).

Thus, the welfare issues associated with the use of laying hens for commercial egg production can relate to both the behaviour and health of the hens. Behaviours can be inhibited by the living environment, for example by preventing the hens from performing nest building, dust bathing, foraging and perching due to a lack of suitable sites for these activities. In addition, some behaviours increase when laying hens are housed under commercial conditions, such as feather pecking and cannibalism. Both the inhibition and exacerbation of behaviours may pose threats to the welfare of laying hens.

In terms of laying hen health, both conventional cage systems and non-cage systems may present threats to the health of laying hens through a variety of vectors. The lack of activity in cage systems can result in weak bone structure, placing the hens at risk of osteoporosis and bone breakages. Bone breakages also occur in non-cage systems, but the majority of bone breakages that occur in non-cage systems are due to the hens colliding with housing features when moving between perches. In addition, the flooring used in both systems can influence foot health, with the mesh size and slope of the flooring in cage systems resulting in foot health problems such as hyperkeratosis, and wet litter in non-cage systems resulting in a high incidence of bumblefoot.

Housing large numbers of birds together may also result in deterioration in their living environment, such as a reduction in air quality due to ammonia and dust production, as well as a build up of parasites and disease, particularly in non-cage systems, due to the birds living in contact with soil, litter and their own faeces. Some of these issues are improved by housing hens in conventional cages, in which birds are not in contact with their own faeces, and disease transmission risk is reduced by decreasing the number of hens that are in contact with each other.

In conclusion, there are common risks to hen welfare posed by both cage and non-cage systems such as overcrowding, however there are also welfare issues that are at greater risk in one system compared to another. Some of the welfare problems, namely osteoporosis and feather pecking, appear to be due in part to selection for high productivity with evidence of a strong genetic component, but the welfare consequences depend on the housing system in which the hen is kept. For example, feather pecking occurs in both cage and non-cage systems, but is at greatest risk and has more catastrophic consequences in non-cage systems. Thus, a comparison of cage and non-cage systems must take into account the threats to welfare that are specific to each system. The movements and behavioural repertoire of laying hens housed in conventional cages are more compromised than hens housed in non-cage systems, however the cage environment generally offers the hens greater protection from feather pecking, cannibalism, parasites and disease. The advantages and disadvantages of the different housing systems are qualitative, and there is currently no objective way of ranking them to determine the overall effect on welfare. For example, how much freedom of movement or freedom to express nesting equates to freedom from disease or injury? The importance that is placed on each of these welfare risks will determine one’s view of the appropriateness of each system.

There is a substantial body of research on the laying hen from each of the different approaches to defining and assessing welfare. Proponents of the ‘natural behaviour’ and ‘affective states’ method of assessing welfare will view non-cage systems more favourably, as the hens are able to preform a greater range of ‘natural’ behaviours. There is good scientific evidence to show that hens are motivated and do prefer to engage in some of these behaviours. However, a proponent of the ‘biological functioning’ method may view a cage system more favourably due to the reduced incidence of disease and cannibalism. Here, the body of scientific evidence clearly indicates advantages of cage systems. Furthermore, this review highlights the importance of the design of the housing system rather than just the housing system *per se*. Good scientific research provides a means of assessing the actual impact of each of these threats to the welfare of laying hens, however this research is far from complete, and the conclusions drawn on the welfare of laying hens are presently reliant on the approach that the researcher uses to assess welfare. What is lacking is a good understanding of how these different approaches to welfare assessment relate to one another.

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