CODE OF PRACTICE FOR THE CARE AND HANDLING OF CHICKENS, TURKEYS AND BREEDERS: REVIEW OF SCIENTIFIC RESEARCH ON PRIORITY ISSUES

November 2013

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Excerpt from the Scientific Committee Terms of Reference

Background

It is widely accepted that animal welfare codes, guidelines, standards or legislation should take advantage of the best available knowledge. This knowledge is often generated from the scientific literature, hence the term "science-based".

In re-establishing a Code of Practice development process, NFACC recognized the need for a more formal means of integrating scientific input into the Code of Practice process. A Scientific Committee review of priority animal welfare issues for the species being addressed will provide valuable information to the Code Development Committee in developing or revising a Code of Practice. As the Scientific Committee report is publicly available, the transparency and credibility of the Code process and the recommendations within are enhanced.

For each Code of Practice being developed or revised, NFACC will identify a Scientific Committee. This committee will consist of 4-6 scientists familiar with research on the care and management of the animals under consideration. NFACC will request one or two nominations from each of 1) Canadian Veterinary Medical Association, 2) Canadian Society of Animal Science, and 3) Canadian Chapter of the International Society for Applied Ethology.

Purpose & Goals

The Scientific Committee will develop a report synthesizing the results of research relating to key animal welfare issues, as identified by the Scientific Committee and the Code Development Committee. The report will be used by the Code Development Committee in drafting a Code of Practice for the species in question.

The full Terms of Reference for the Scientific Committee can be found within the NFACC Development Process for Codes of Practice for the Care and Handling of Farm Animals, available at www.nfacc.ca/code-development-process#appendixc.

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INTRODUCTION

The following document has been compiled by the Scientific Committee based on priority welfare issues. It is important to note that "meat birds" is a very encompassing group, and includes turkeys, broilers and broiler breeders. Because of the three species, a total of nine priority welfare issues were documented:

1. Male to female aggression in broiler breeders
2. Feed restriction in broiler breeders and turkey breeders
3. Feather pecking and cannibalism in broiler breeders and turkeys
4. Air and litter quality
5. Stocking density
6. Lameness
7. Lighting regimens
8. Methods of euthanasia
9. Surgical interventions in turkeys.

The majority of research documented in these sections focuses on broilers. While many factors will also apply to turkeys, it should be noted that, although growing conditions are often the same, and although broilers and turkeys are biologically similar, they are different species. Therefore, their response, or level of response, may be different to particular variables. While the availability of research using turkeys is limited, it is also important to note that much of it is dated.

1. MALE TO FEMALE AGGRESSIVE MATING IN BROILER BREEDERS

CONCLUSIONS

1. **The cause and development of male to female aggressive mating in male broiler breeders is not clear but two main contributors appear to be genetics of the birds and early learning experiences.**
2. **Broiler breeder males show a clear lack of courtship behaviour and this appears to contribute to male to female aggression during mating and lack of willingness to mate from the females.**
3. **Increased aggression in male broiler breeders towards females during mating appears to have a genetic basis, but the impact of management factors such as separate rearing of males and females still needs to be studied.**
4. **In limited research, the ratio of males to females has not consistently been shown to impact male to female aggressive mating.**

INTRODUCTION

During mating, male broiler breeders often exhibit forced and rough sexual behaviour towards females (Millman & Duncan, 2000b). This aggressive behaviour is present when males and females first interact, and has been found to occur more frequently than aggressive behaviour between males (de Jong et al., 2009). Particularly aggressive males have been observed to pull females by the comb from a group ‘corralled’ or huddled in the corner of the pen and often chase or peck this now ‘stray’ female (Millman et al., 2000). In response to the males, females show fearful behaviour such as huddling, alert postures and alarm calls (Millman et al., 2000) and often try to escape from the males during mating (de Jong et al., 2009). Females can also become severely injured by the males, with injuries leading to culling (Millman et al., 2000).

Measures for evaluating the welfare of broiler breeders with regard to aggression can include the biological function of the animals (health and productivity), their affective state (subjective experiences) and naturalness (the ability to express important behaviours). Research to date has largely focused on the occurrence and incidence of the aggressive behaviours themselves.

1. In terms of biological functioning, studies have looked at some production parameters, mainly focusing on fertility. Injuries such as lesions and scratches on the females are considered a negative consequence of male to female aggressive mating but have rarely been measured.
2. In terms of affective states, behaviours such as forced copulations and fleeing by females are considered to indicate distress in hens and are often assessed in order to determine potential differences in environment or genetic factors among the birds.
3. In terms of natural living, male to female aggressive mating is not observed in flocks of jungle fowl, and therefore provides some evidence that it is an abnormal behaviour.

While male to female broiler breeder aggression around mating is both a production and animal welfare problem, the cause and development is not completely clear. It is generally thought that this heightened aggression of males towards females has a genetic basis. However, the roles of decreased or absent courtship and separate rearing of males and females have not been elucidated, and it's unclear if the two are linked (Duncan, 2001). It is possible that both increased aggression and courtship deficiency are related to a trait such as increased breast size which has been heavily selected for in broiler production (Duncan, 2001), but this remains to be determined.

POTENTIAL CAUSES OF AGGRESSION IN MALE BROILER BREEDERS

<u>Inadequate courtship by males:</u> Sexual behaviour in broiler breeders appears to be incomplete or immature, with males behaving roughly and females not responding to the males' approach (de Jong et al., 2009). Males appear to be motivated to copulate, but are not communicating this with the females, either through their inability or lack of motivation to perform courtship behaviour (Millman et al., 2000). Certain courtship behaviours such as waltzing, tidbitting and high step advances appear at low frequencies or not at all in commercial broiler breeders (de Jong et al., 2009), in comparison to their high frequency in laying strains during mating (Millman et al., 2000).

Other elements often considered part of the courtship repertoire, such as feather ruffling, crowing and wing flapping, were performed without contextual cues, and may not have been recognized by the female as being courtship-related (de Jong, et al., 2009). Broiler breeder females housed with males were rarely observed assuming a sexual crouch, which resulted in copulation that often followed a chase (Millman et al., 2000).

The separate rearing of male and female broiler breeders may contribute to the lack of adequate courtship behaviour by the males (de Jong et al., 2009), as well as the poor response by the females. Sexual behaviour begins to develop as early as five weeks of age and aggressive behaviour develops in the first week of age. Aggression has also been noted in jungle fowl reared without the opposite sex (Kruijt, 1964, cited by de Jong et al., 2009), suggesting that experience interacting with females and fighting with other males influences the development of sexual behaviour of adult male fowl. Although this has been speculated as a cause for the problem, no studies have systematically addressed the effects of same-sex rearing on aggressive or sexual behaviour in broiler breeders. Mating success rate may be highest when the early experiences of both the males and females are similar. A higher success rate for mating attempts was found either 1) when both sexes were reared in mixed sex groups or 2) when both sexes were reared in same-sex groups than if one sex was reared in a mixed sex group and one was reared in a same-sex group (Leonard et al., 1993).

Doherty (2006) found that sexually mature males subsequently housed with hens for five weeks showed more courtship behaviour when tested with novel females than did males without the additional experience, indicating that learning plays a role. However there were strain by treatment interactions and experience did not completely eliminate the deficiencies in courtship and the aggressive behaviour that broiler breeder strains exhibited toward females.

Another aspect that may lead to aggressive mating behaviour is the large body size of the males impeding their mating ability, leading to frustration (Millman & Duncan, 2000b). Broiler breeder males performed more unsuccessful mating attempts and mounts than laying strain males, either because the males were unable to achieve cloacal contact as a result of their large size or because the female successfully escaped the male (Millman et al., 2000). McGary et al. (2003) found a higher frequency of male to female aggression and forced matings in younger rather than older males, and an effect of selection for high breast yield. However, Millman et al. (2000) hypothesized that while the large size of the male likely contributed to the difficulty in mating, the willingness of the female seems to be more important in determining mating success. Doherty (2006) found that morphological characteristics such as body weight, comb and wattle size of individual broiler breeder males was not predictive of their sexual or aggressive behaviour toward females. The relationship between sexual chracteristics and mating behaviour is not straightforward, as Bilcik et al. (2005) found a positive correlation between mating attempt frequency and comb size, while McGary et al. (2003) found a positive relationship between comb size and reproductive behaviour in some strains but not others.

Genetic strain differences: Differences in generalized aggression do exist in domestic fowl strains. When presented with a male model, broiler breeder males exhibited lower levels of aggression than males from game strains bred for cock fighting, and equal or lower levels than laying strain males (Millman & Duncan, 2000c). Broiler breeder males behaved aggressively towards females, while game strain males did not display high levels of aggressive mating towards females, but rather displayed extremely high levels of aggression when presented with a male model (Millman & Duncan, 2000b). If male to female aggressive mating was due to a general increase in aggression, it would be expected that these highly aggressive fighting males would show higher levels of aggression towards females than broiler breeder males. The absence of this response provides evidence that it is not a general increase in aggression that causes male broiler breeders to act aggressively towards females.

When given the choice between broiler and laying strain males, broiler breeder females showed no consistent preference between the two strains (Millman & Duncan, 2000a). However, females with experience tended to choose the laying strain rather than the broiler breeder strain males. Thus, the authors suggested that the avoidance by females of broiler breeder males is a result of learning and not due to the morphology or behaviour of the males. Females rarely struggled during mating attempts by laying or game strain males but struggled much more frequently during mating attempts of broiler breeder males (Millman & Duncan, 2000b).

In addition to the genetic differences mentioned above, some researchers have found differences in male to female aggressive mating between broiler breeder strains, possibly due to differing motivations to mate (McGary et al., 2003). Others found no differences between broiler breeder strains in the frequency of aggressive behaviour such as pecking or chasing females, in male to male aggression, or in mating attempts (Doherty, 2006; Millman et al., 2000). However, females responded differently to the different strains of broiler breeder males, suggesting that there could be subtle differences in the interaction between males and females that play a role in aggression.

Male to female ratio in the group: It is unclear if subtle differences in the male to female ratio within groups of broiler breeders influence mating aggression. No difference in the frequency of forced matings was seen between groups of one male and ten females or three males and ten females (Bilcik & Estevez, 2005). However, the sex ratio may interact with experience; males from groups of 3:10 increased their mating frequencies and cloacal contacts after they were moved to groups of 1:10, whereas males from groups of 1:10 decreased their mating frequencies when moved to groups of 3:10 (Bilcik & Estevez, 2005). Additionally, Campo and Dávila (2002) found an effect of the sex ratio on tonic immobility, with males housed at a ratio of 1:1 in groups of 240 (120 males and 120 females) having shorter duration of tonic immobility than those housed at a ratio of 1:11 (20 males and 220 females). This suggests that fearfulness and aggressiveness are influenced by the ratio of males to females within a pen. The duration of tonic immobility did not differ between groups of hens, but hens housed at 1:1 ratios had higher heterophil:lymphocyte ratios than hens housed at 1:11 (Campo & Dávila, 2002).

Environmental factors: The impact of environment on the development of male to female aggressive mating in broiler breeders has received little attention to date. Stocking density has been suggested as a potential factor influencing aggression (de Jong & Guémené, 2011), where lower stocking density may improve copulation success and decrease feather damage. This research is ongoing and is not yet conclusive. Lighting regimen has been investigated as a potential factor affecting male behaviour, but no impact was found (Moyle et al., 2012). Leone and Estevez (2008) demonstrated that the use of panels in commercial broiler breeder flocks significantly improved fertility.

Feed restriction: Feed restriction had an impact on the amount of aggression observed within groups of male broilers (Mench, 1988). Pecking and threatening occurred more frequently in chicks fed every other day than those fed *ad libitum*, particularly on off-feed days. Aggression occurred mainly at the feeder, and after four days of full feed, aggression in chicks that had previously been fed every other day was reduced to its lowest level (Mench, 1988). However, no females were present in this study, and two decades of genetic selection may make these results irrelevant to today's strains of broiler breeders.

More recently, Millman and Duncan (2000b) examined the effect of feed restriction on male to female broiler breeder aggression. Feed restriction delayed sexual maturity, but sexual behaviour and aggression of restricted fed broiler breeder males did not differ from *ad libitum* fed laying strain males. Similar frequencies of copulation, forced copulation and mounting were found in a laying strain and two different broiler breeder strains fed either restrictively or *ad libitum*, although the full-fed males were actually more aggressive (pecking and chasing) than the feed-restricted males (Millman et al., 2000). Feed restriction during rearing also did not impact the level of aggression of males towards a frozen male model (Millman & Duncan, 2000c). In these experiments, aggression at the feeder was not measured. Had there been increased feeding aggression it may have indicated that the aggression was specific to feeding and not due to a general increase of aggression in males. The majority of male to female aggression occurs outside of the feeding period so these problems appear to be separated in time and with regard to motivational systems. Futhermore, males and females are usually fed in separate locations and males are prevented from accessing the female feeders. Despite this, aggression may still be related to hunger-induced frustration.

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2. FEED RESTRICTION IN BROILER BREEDERS AND TURKEY BREEDERS

CONCLUSIONS

1. **The level of feed restriction used commercially reduces the welfare of the birds through chronic hunger.**
2. ***Ad libitum* feeding of broiler breeders results in production and health problems such as reduced fertility and ascites, as well as increased mortality.**
3. **Genetic selection should consider not only production increases, but also how to relieve associated side effects such as the need to restrict feed to breeder stock.**
4. **Alternative diets can improve the welfare of birds by reducing feather pecking.**

INTRODUCTION

The welfare of feed restricted birds can be assessed through their biological function, affective states and ability to perform natural behaviours. Depending on which approach is used, the evaluation of the birds' welfare may vary.

1. In terms of biological functioning, production and health parameters are often used. Production parameters include growth, feed intake, egg production traits, and age of fertility. Health parameters include mortality, skeletal deformities and ascites, although these are often overlooked.
2. In terms of affective states, feed restriction practices can be assessed based on behaviours indicative of hunger, such as high levels of activity, stereotypic pecking, increased water use and feeding motivation. Physiological measures such as cortisol and heterophil:lymphocyte ratio are also used as indicators of stress.
3. Natural living can be examined through the time spent eating and the time spent performing various other behaviours such as sitting, standing and foraging.

BACKGROUND

Broiler and turkey breeders have the potential to grow very quickly due to genetic selection for feed conversion. However, feeding them to satiety leads to metabolic and fertility problems, and increases in mortality (Savory et al., 1993; Decuypere et al., 2010). Health problems such as ascites and skeletal deformities (which may lead to hock burns and breast blisters) occur in *ad libitum* fed broiler breeders, and feed restriction can dramatically reduce these problems (Mench, 2002). Commercially, feed is restricted most often through the provision of a limited amount of feed daily, or a larger (albeit still restricted) amount every other day (referred to as 'skip-a-day' feeding; Mench, 2002).

Feed restriction begins as early as 7-10 days of age for some strains, and as late as four weeks of age for others (Leeson & Summers, 2000), with the most severe restriction occurring during rearing. After breeders reach lay, restriction levels decrease. However, with commercial lines of breeders, it is still necessary to continue some level of feed restriction. Broiler breeders fed *ad libitum* from 37 weeks of age (post peak egg production) had depressed egg production and lower fertility and hatchability than birds fed a restricted quantity of food according to the breeder's recommendations (Hocking, 1998). Females that were fed *ad libitum* after peak egg production were found to have a rapid weight increase, and by 60 weeks of age, weighed the same as birds fed *ad libitum* throughout. However production does not decrease to the same extent with restricted feeding as is seen with *ad libitum* feeding (Hocking et al., 2002).

IMPLICATIONS OF FEED RESTRICTION

The objective of feed restriction is to control weight gain to facilitate optimum health and productivity. Recommended feed allocation can be as little as 33% of *ad libitum* access (de Jong et al., 2002), an amount that some broiler breeders can consume in as little as five minutes (Savory et al., 1993).

Effect on behaviour: Feed restricted birds are highly motivated to eat. In a motivation test, de Jong et al. (2003) found a linear relationship between compensatory feed intake and the level of feed restriction. However, even immediately after a meal, feed restricted birds were still hungry and worked harder for access to more food than birds fed *ad libitum* but deprived of food for 72 hours (Savory et al. 1993).

High levels of activity are often associated with restricted fed broiler breeders (Kostal et al., 1992; Savory & Lariviere, 2000). This is likely due to increased feeding motivation, as increased meal size influences time spent active at the feeder (Savory & Mann, 1999). Restrictively-fed breeders spent less time sitting and more time standing during rearing than birds fed *ad libitum* (de Jong et al., 2002; Hocking, 1998; Sandilands et al., 2005). The amount of walking was also found to differ (de Jong et al., 2002; Neilsen et al., 2003; Savory & Maros, 1993), although not in all studies (Hocking, 1998).

Behaviours such as pecking at the feed trough, over-drinking and object pecking also differ depending on level of feed restriction. As they age, restricted-fed birds increased their frequency of spot pecking (Hocking et al., 2001; de Jong et al., 2002), while those fed *ad libitum* either decreased (Savory & Maros, 1993) or didn't change their pecking behaviour (de Jong et al., 2002).

Individual birds show a variety of stereotypical behaviour as well as a variation in the amount of stereotyped activity shown (Kostal et al., 1992). Broiler breeders often display repetitive drinking and stereotyped spot-pecking (Savory et al., 1992). To combat this excessive drinking, producers often remove the drinker to control litter wetness (Kostal et al., 1992). In some cases, this results in the behaviour being redirected to other objects, but occasionally it leads to increased preening, litter-directed activity and standing (Kostal et al., 1992).

Time spent on comfort behaviour is negatively related to the level of restriction, where birds first satisfy their need for food and then will start to perform comfort behaviours (de Jong et al., 2003). Feeding level may also impact certain courtship behaviours; waltzing was performed twice as much by *ad libitum* fed males compared to restricted fed males, but no difference was found in the frequency of tidbitting and high step advances (Millman et al., 2000).

Effect on physiology: Physiological measurements are tools used to indicate stress or poor welfare, but physiological changes themselves do not necessarily reflect poor welfare. Plasma corticosterone concentrations increase as a consequence of psychological stress, but they may also be impacted by the metabolic effects of food restriction (de Jong et al., 2002). Broiler breeders fed restrictively have been found to have significantly higher baseline plasma corticosterone concentrations than those fed *ad libitum* (de Jong et al., 2002; 2003; Hocking, 1998; Hocking et al., 2001; Savory et al., 1996). In contrast, the heterophil:lymphocyte ratio, which is often used as a measure of chronic stress, was not found to be significantly different at either 21 or 42 days of age (de Jong et al., 2002).

ALTERNATIVE METHODS OF CONTROLLING GROWTH RATES

Alternative diets: Alternative diets can increase satiety through inclusion of lower quality foodstuffs such as oat or soybean hulls to decrease the energy density of the diet or decrease hunger through the inclusion of compounds such as calcium propionate to suppress appetites (D'Eath et al., 2009). This allows animals to terminate feeding on their own terms while food is available, and to express normal feeding behaviour (D'Eath et al., 2009). While alternative diets can improve welfare to some degree, qualitative restriction doesn't impact the overall feeding motivation of the birds (Savory & Lariviere, 2000).

Effect on body weight and production: There are conflicting data on whether the use of dietary diluents alone in broiler breeders' diets can improve feed efficiency or maintain body weights (Zuidhof et al., 1995; Sandilands et al., 2006). However, the combination of fibre and an appetite suppressant has been found repeatedly to control weight gains (Tolkamp et al., 2005; Sandilands et al., 2006; Morrissey, 2012). Reducing levels of protein in the diet can be used as a means of controlling weight gain. Birds that were fed a low protein ration *ad libitum* had a body weight of half that of birds fed a high protein diet, a difference that remained until 24 weeks of age (Hocking et al., 2001). Alternative diets often result in lowered body weight uniformity (Savory et al., 1996), which may increase variability in start of lay and require additional management of the birds (Savory et al., 1996).

Egg production curves were found to be similar between birds fed a control quantitative restriction and those fed a diet with added oat hulls or soybean hulls and calcium propionate (Tolkamp et al., 2005; Morrissey, 2012). Egg production was highest in female broiler breeders fed a standard diet diluted with 15% ground oat hulls compared to 30% diluted or undiluted diets (Zuidhof et al., 1995). No treatment effect was found with regard to egg weight or shell quality (Tolkamp et al., 2005).

Water intake was decreased in birds fed a low protein diet with restricted intake; however, these birds were lighter in body weight (Hocking et al., 2001). Water intake (Hocking, 2006) and time spent at the water source (Zuidhof et al., 1995) were significantly decreased in birds fed a diet diluted with oat hulls compared to a control diet. Litter moisture was also lower with increasing concentration of oat hulls, leading to decreased number of litter changes (Hocking, 2006).

Effect on behaviour: Morrissey (2012) found that a diet with 40% soybean hulls and calcium propionate led to significantly better feather condition and less feather pecking than a control (restricted) diet. Quantitatively restricted fed birds have been noted to have a high frequency of object pecking, spending upwards of 50% of the time performing this behaviour while object pecking was nearly nonexistent in birds fed a qualitatively restrictive diet (Sandilands et al., 2006). Conversely, only small differences in sitting behaviour were seen in the same study, a behaviour which has been used to indicate the severity of the food restriction (Sandilands et al., 2006). A decrease in stereotypic object pecking and an increase in sitting have been achieved at 6 and 10 weeks of age using lower density diets. However this decrease disappeared by 16 weeks and birds still spent at least 40% of the observed time pecking at objects, suggesting that the reduction in hunger or frustration is relatively small (de Jong et al., 2005). The time spent object pecking was also not reduced by varying the amount of protein available in a restricted ration (Hocking et al., 2001). Generally few differences in time budgets of birds fed on different rations have been noted; however, linear decreases in spot-pecking were seen with increasing concentrations of fibre through both oat hulls and beet pulp, but not with sunflower meal (Hocking et al., 2004). It is suggested that the welfare of birds fed sugar beet pulp is improved due to the increased water holding capacity of the feedstuff, which induces a sense of satiety in the crop and gizzard (Hocking et al., 2004); however physiological indices do not consistently support this claim (see below) (Savory et al., 1996). Broiler breeder females fed alternative diets have more feed to consume, allowing them to spend 30-38% of their time eating (Sandilands et al., 2006), which is much more than quantitatively restricted fed birds spend.

When offered control and alternative diets *ad libitum*, birds strongly preferred the control, high density diet to the same diet with added calcium propionate or added fibre (Buckley et al., 2011; Torrey et al., 2013). However, when feed restricted and offered the choices in a maze, birds were unable to learn the task and display a preference, perhaps because of their severe level of hunger (Buckley et al., 2011).

Effect on physiology: The effect of alternative diets on physiology is not clear. In one experiment, corticosterone concentrations were higher for birds fed a restricted diet high in protein than those fed low protein or birds fed high or low protein diets *ad libitum* (Hocking et al., 2001). However, in a similar experiment, no differences in corticosterone concentrations were found between diets or level of feeding (Hocking et al., 2002). Diets containing oat hulls and/or calcium propionate did not affect the white blood cell levels (Sandilands et al., 2006). Increasing the amount of fibre in the diet using oat hulls also did not cause a variation in corticosterone concentrations or immune response in birds at 16 weeks of age (Hocking, 2006). The addition of oat hulls to the diet did reduce the heterophil:lymphocyte ratio at 12 weeks of age, but this difference was not evident at 20 or 50 weeks of age (Zuidhof et al., 1995). Savory et al. (1996) found broiler breeders fed a basal mash diet with added unmolassed sugar beet pulp had a significantly higher heterophil:lymphocyte ratio at both 6 and 10 weeks of age, suggesting that this type of diet increased physiological stress, which the authors suggest is associated with its high absorbency. In other results, broilers fed rations with sugar beet pulp had lower heterophil:lymphocyte ratio, a lower basophil count as well as a lower prevalence of damaging pecking than either a control diet or rations including oat hulls or sunflower meal, despite lower body weights (Zaczek et al., 2003).

Skip-a-day feeding regimen: Skip-a-day feeding regimen is a method used to restrict feed intake in broiler breeders by feeding approximately twice the daily restricted feed allowance every alternate day (or every third day with skip-two-days feeding; Leeson & Summers, 2000). Skip-a-day or skip-two-days feeding regimens were suggested as a method of controlling uniformity in flocks by reducing the competition for feed (Bartov et al., 1988). However, the success of these feeding regimens is unclear. Bartov et al. (1988) found improvements in uniformity with skip-two-days rather than skip-a-day feeding, and males in a study by Mench (2002) had greater uniformity with skip-a-day rather than daily feeding. Yet, others found no differences between birds fed daily or every other day (Bennett & Leeson, 1989; Gibson et al., 2008). Daily fed birds are generally heavier than skip-a-day fed birds, perhaps because they are able to utilize feed more efficiently (Bennett & Leeson, 1989). However, these results are not consistent, as Morrissey (2012) found no weight differences between daily and skip-a-day fed hens. Pullets reared on a skip-two-days feeding regimen were found to be significantly and consistently lighter than those fed on a skip-a-day regimen despite essentially the same total feed consumption per pullet (Bartov et al., 1988). This weight differentiation noted at 22 weeks of age was still present at 35 weeks of age after daily feed allowance from 23 weeks of age, even though birds reared on skip-two-days feeding gained significantly more weight in this time (Bartov et al., 1988). Birds fed with the skip-a-day method consume their feed in a short period of time and may be without feed for up to 46 hours (Leeson & Summers, 1985). Birds therefore likely obtain their necessary nutrients during this time through catabolism of body reserves, which decreases the efficiency of this system (Leeson & Summers, 1985).

Pullets reared on skip-two-days feeding had significantly higher age at first egg, an effect attributed to the low body weights of these birds (Bartov et al., 1988). Skip-a-day feeding may also result in a decrease in egg production throughout the production cycle, likely due to impacts of feed restriction during ovarian development (Gibson et al., 2008). However, results are equivocal as others (Morrissey, 2012) found no effect of skip-a-day feeding on egg production.

Because of the perceived insult to welfare, feeding regimens that do not provide daily access to feed are banned in Sweden and the United Kingdom (UK) (European Food Safety Authority, 2010). However, little data exist on the welfare implications of non-daily feeding of broiler breeders. Morrissey (2012) found that skip-a-day birds feather pecked more during feeding bouts, but had better feather condition, than daily fed birds.

Genetics: There is a strong negative relationship between body weight and reproductive efficiency in poultry (Decuypere et al., 2010). Fast growing broiler chickens have poor reproductive performance, while slow growing laying hens have been optimized for reproduction. As selection is focused on growth, improving reproduction in broiler breeders is generally done through management techniques, such as restricting feed intake (Decuypere et al., 2010). This has been labelled the 'broiler breeder paradox' by Decuypere et al. (2010), where it appears impossible to sustain the high production requirements such as good reproductive performance and good health without severely restricting energy intake.

One way to reduce the reliance on feed restriction for good reproductive performance is to include slower growing strains within genetic selection parameters. The practice of mating heavy broiler males with slow growing dwarf females has been used with some success (Heck et al., 2004). Because dwarf hens can be fed a dilute diet *ad libitum* and still maintain an acceptable level of reproduction (Heck et al., 2004), the sex-linked, recessive dwarf gene could be incorporated to reduce the need for feed restriction in broiler breeders without any major implications on the broiler offspring (Decuypere et al., 2010). This possibility requires further investigation to determine its practicality in the Canadian poultry industry.

Environmental enrichment: Environmental enrichment in the form of bales of wood shavings and bunches of string redirected pecking behaviour, and reduced overall stress responses in feed restricted broiler breeders (Hocking et al., 2005), but it is unclear if it impacted feeding motivation specifically. The availability of litter allows birds that are feed restricted to forage, and decreases the stress of feed restriction, seen by lower levels of feather pecking as well as lower plasma corticosterone concentrations (Hocking et al., 2005). Litter condition should be maintained in order to facilitate this foraging behaviour (Hocking et al., 2005).

RESTRICTED FEEDING OF BREEDING TURKEYS

Feed restriction is used as a tool in commercial turkey breeding production to control the body weight of male male-line turkeys to improve semen production and reduce the effects of heat stress in hot climates (Hocking, 1999). The prevalence of musculo-skeletal lesions and weight related disorders can be decreased in males and females using feed restriction, thereby improving survivability and the welfare of the birds (Hocking, 1999).

<u>Effect on production:</u> Feed efficiency was not consistently impacted in nine studies reviewed by Hester and Stevens (1990) where fibre was added to the diet and intake was limited or skip-a-day feeding was employed. Feed consumption and 30 week body weights of female turkeys was inversely related to sexual maturity, measured as age at first egg or age at 25% production, and so feed restriction is considered a viable option to delay sexual maturity (Voitle et al., 1973). Females of female-line turkeys restricted fed from 3 to 16 weeks of age were more prolific egg producers early in the laying period, but cumulatively there were no significant differences in egg production between restricted fed or *ad libitum* fed females (Crouch et al., 1999). Hester and Stevens (1990) reviewed several studies where female turkeys (generally Large White strain) were restricted and found that in general, breeders that were fed restrictively had delayed sexual maturity, but no consistent effects on overall fertility, egg hatch, egg weight or egg production were found.

<u>Effect on behaviour:</u> Restricted feeding of turkeys has similar effects on behaviour as is seen with broiler breeders, where oral activity, specifically pecking at walls, is increased and the proportion of time spent sitting and preening is decreased (Hocking, 1999).

<u>Effect on physiology:</u> Corticosterone concentrations were higher during rearing with feed restriction, but the heterophil:lymphocyte ratio and basophil levels were not affected (Hocking, 1999). The authors suggested that either the feed restriction was not as severe as those imposed on broiler breeders, or perhaps turkeys are better adapted to the physiological demands of restricted feeding than broiler breeders (Hocking, 1999).

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3. FEATHER PECKING AND CANNIBALISM IN BROILER BREEDERS AND TURKEYS

CONCLUSIONS

1. **The causes of feather pecking and cannibalism are not clear, but for feather pecking one of the main causes seems to relate to foraging behaviour. They are both multifactorial and factors which impact their prevalence include hunger, high stocking density and genetic propensity.**
2. **Injurious forms of pecking in turkeys occur as both aggressive pecking and feather pecking. Aggressive and feather pecking have been reduced in turkeys by decreasing the light intensity or by the addition of straw or objects to pens.**
3. **Emphasis should be on prevention of feather pecking outbreaks as once they begin, it is difficult to abolish the behaviour.**

INTRODUCTION

Measures for evaluating the welfare of chickens and turkeys in regard to feather pecking, head pecking and cannibalism have centered primarily on mortality and feather or skin damage. Thus, the biological function of the animals (health and productivity) is the main focus. While pecking and cannibalism in turkeys are major welfare issues, the prevalence and impact of the behavioural problems in broiler breeders are largely unknown (de Jong & Guémené, 2011). It is likely that the birds affected experience pain (Gentle & Hunter, 1991), and often vocalize and move away, indicating that this is an aversive experience. Feather eating is a natural behaviour in some types of birds and pecking is used to establish and assert dominance in the wild, but the level that is seen in commercial production does not likely serve this purpose and has not been recorded in nature. The majority of in-depth research on the development and causes of feather pecking has been done on laying hens and this area is covered in the *Code of Practice for the Care and Handling of Poultry (Layers): Review of Scientific Research on Priority Issues* as well. It is possible that the same mechanisms underlie feather pecking in all of the poultry species. Laying hen literature regarding factors that appear similar in broiler breeders and turkeys are discussed in this review.

TYPES OF PECKING

Feather pecking can be categorized into different types of pecking depending on the cause and consequence. Savory (1995) has classified types of pecking in laying hens as the following:

1. Aggressive pecking: directed by dominant birds to subordinates, the objective is to establish and maintain dominance. It is usually aimed at the head and is delivered with force. It can cause tissue damage and if it persists can lead to severe injury or death if the recipient can't escape.
2. Gentle feather pecking without removal: causes little or no damage and may appear to be directed at particles of litter or food as opposed to the feathers themselves. This type of pecking is usually ignored by the recipient.
3. Severe feather pecking leading to feather loss: the feather is grasped and firmly pulled and may cause the recipient to vocalise and withdraw. The feather may be removed and is sometimes eaten. Feather damage or feather loss results.
4. Tissue pecking in denuded areas: forceful pecking is directed at exposed skin and is often persistent. This type of pecking may lead to hemorrhage and the appearance of blood may stimulate more pecking and other birds to join in. Generally the damage is severe and death or culling can result. Attempts by the recipient to avoid the pecking by moving away are generally unsuccessful, as the pecking birds will follow.

5. Vent pecking: similar to tissue pecking but appears to be a separate behaviour. This type of pecking is generally seen soon after birds come into lay and may be linked to hormonal changes. Vent pecking is more likely to occur in floor systems where birds lay their eggs on the floor in crowded areas. Vent pecking seems to be initiated at oviposition when a minor partial prolapsed uterus occurs and exposure of the mucous membrane stimulates pecking. Vent pecking may begin as investigatory behaviour but can quickly escalate and lead to death from blood loss. The pecking may continue after death with abdominal organs being removed.

The divisions between these classifications are not always clear. While aggressive pecking and vent pecking appear different, the other pecking behaviour patterns are not always distinct and can grade into each other (Savory, 1995). Aggressive pecking is seen primarily in turkeys, while vent pecking is an issue in broiler breeders, and possibly turkey breeders. Feather pecking and tissue pecking are found in both species.

Feather pecking is often measured by damage to the bird, generally on the back, tail, neck and wings. Each of these areas can be scored based on the extent of the damage or area of bare skin.

POTENTIAL CAUSES OF FEATHER PECKING AND CANNIBALISM

In laying hens, feather pecking, aside from vent and aggressive pecking, was hypothesized to be redirected ground pecking, either as an element of foraging or dustbathing (Savory, 1995). Increased feather pecking on bare slatted floors in comparison with litter floors may represent an inverse relationship with ground pecking. Savory (1995) suggested that feather pecking represents an underlying inclination to peck and that the environmental and genetic factors influence how and towards what this pecking is expressed.

Hughes and Grigor (1996) suggested that beak-related behaviours are an important part of the behavioural repertoire of turkeys and one beak related behaviour may be at least partly substitutable for another. For example, a reduction in feeding time between weeks 5 and 6 due to a change from a crumbled diet to a pelleted one was associated with a slight increase in feather pecking (Hughes & Grigor, 1996).

<u>Nutritional factors:</u> Feed restricted birds (i.e. broiler breeders) are highly motivated to eat and often this leads to object pecking or other redirected foraging (Sandilands et al., 2005; Savory & Lariviere, 2000). Pecking damage has been found to be worse when bantam chicks were fed pelleted food compared to mash or diluted mash (Savory et al., 1999), or turkeys were fed pellets compared to a crumble (Hughes & Grigor, 1996) presumably by limiting foraging opportunities. Increasing ground pecking and time spent feeding (through the use of a mash diet) reduced the risk of feather pecking in laying hens (Savory, 1995). Broiler breeders on a skip-a-day feeding regimen did not have different feather scores (correlated to feather pecking) compared to those fed every day, but feather scores of daily fed broiler breeders did worsen more quickly over time than those fed every other day (Morrissey, 2012). When feed is restricted, pecking and scratching are more common after rather than before feeding, further implicating the relationship among feeding and hunger, foraging and pecking (Savory, 1995). Hocking and Jones (2006) showed no effect of enriching broilers breeders with bales of straw or string on feather condition, aggression or other types of behaviour and concluded that environmental enrichment was not sufficient to reduce high feather damage or alleviate the effects of frustration due to hunger.

Certain nutrients can also impact the level of feather pecking. Pecking damage was reduced at 4 and 6 weeks in growing bantams fed a diet supplemented with L-tryptophan, which is known to have sedative properties (Savory, 1998; Savory et al., 1999). Feeding alternative diets with added appetite suppressant (calcium propionate) improved feathering scores in broiler breeder hens pre-lay and after the onset of lay (Morrissey, 2012). Dietary protein source (plant or animal based) does not appear to impact the rate of feather pecking in laying hens (Savory, 1998).

Feather pecking and cannibalism have also been hypothesized to develop out of feather eating. Feather eating is common in some waterfowl to aid digestion (Piersma & van Eerden, 1989); however, domestic birds cannot break down keratin in the digestive tract and therefore cannot use feathers for this purpose. McKeegan and Savory (1999) found an association between feather eating and feather pecking in layer pullets, but this association was not strong enough to establish a causal link. It was proposed that once feather eating is established, if the preferential feathers are not available on the ground, then feather eating and pecking is directed towards other birds (McKeegan & Savory, 1999).

Environmental factors: Stocking density impacts the incidence of pecking damage in larger but not smaller groups of growing bantams at 4 and 6 weeks of age. Pecking damage was worse in groups of 20 birds housed with the highest density (186cm^2 per bird) compared to groups of 10 birds with a lower density (744cm^2) (Savory et al., 1999). No effect of group size was found at a stocking density of 372cm^2 per bird (Savory et al., 1999). In large groups of birds, as is seen in commercial housing, group size may be less important than stocking density. Increased stocking density may be related to the increased level of feather pecking found by Drake et al. (2010) in laying hens kept in houses with higher carbon dioxide or ammonia levels. Other environmental factors such as type and height of feeders, and month of the year also impacted the level of feather pecking (Drake et al., 2010).

Genetic factors: The incidence of feather pecking and cannibalism varies among different strains of birds (Muir & Craig, 1998; Jendral & Robinson, 2004). Individual selection based on performance can lead to increased competion among individuals (Rodenburg, 2010). For example, individual selection for heavy body weight in Japanese quail resulted in a large increase in mortality due to aggression and cannibalism (Muir, 2005). There may also be differences in the level of aggression and how pecking is targeted. Variation also exists within flocks and generally a few individuals account for most of the pecking, although the behaviour can be transmitted throughout flocks as a result of social facilitation (Cloutier et al., 2002).

Differences have been investigated between and within strains of laying hens and selection against these behaviours has had positive results (Muir & Craig, 1998). Evidence for strain differences has also been reported in turkeys, where a selected male line exhibited much higher levels of severe feather pecking and injuries than turkeys of a traditional line (Busayi et al., 2006). Selection of individuals and strains of meat birds with lower levels of feather pecking and cannibalism requires more investigation, but could prove to be a powerful tool.

Sex differences: Injuries due to feather pecking have been found to be more frequent in male turkeys than in females (Busayi et al., 2006). Similarly, Martrenchar et al. (2001) found head injuries to be more frequent in male turkeys than female turkeys at 5 weeks of age and tail injuries to occur more in groups of male turkeys at week 10.

PREVENTION AND CONTROL OF FEATHER PECKING AND CANNIBALISM

Preventative measures are often taken to reduce the damage caused by feather pecking and cannibalism. Beak trimming is one of these measures. Beak trimming is covered in more detail in the *Code of Practice for the Care and Handling of Poultry (Layers): Review of Scientific Research on Priority Issues for Laying Hens*, with some information regarding turkeys available in this report in the section *Surgical Interventions in Turkeys*.

Another way that feather pecking can be reduced is through the use of low light intensities (generally 2 to 5 lux for turkeys) or red lights. High levels of pecking injuries were resolved by reducing the light intensity from 10 to 5 lux in growing turkeys (Sherwin et al., 1999a). Pecking injuries in turkey poults were not impacted by light intensities of 5 lux or 10 lux in one experiment (Moinard et al., 2001) but were positively correlated with light intensity when 5, 10, 36 and 70 lux of fluorescent light were compared in a companion study (Moinard et al., 2001). Injuries to the tail and wing of turkeys were less common under fluorescent light than incandescent light (Moinard et al., 2001). Conversely, Sherwin et al. (1999b) found no difference in wing or tail pecking injuries in turkeys reared in fluorescent or incandescent light.

Environmental enrichment has also been investigated as a measure to prevent feather pecking in turkeys. A barren environment lacking stimulation is thought to exacerbate feather pecking. Environmental enrichments (a wooden board with objects attached, plastic conduit lengths, two connected boards with aluminum foil between, cabbages and supplemental spot lighting) for turkeys significantly reduced the injuries caused by wing and tail pecking, and the number of birds that had to be culled or died due to pecking injuries when compared to controls (Sherwin et al., 1999a). Access to perches or novel objects also reduced turkey pecking rates and mortality compared to controls (Crowe & Forbes, 1999). There was an inverse relationship between pecking and interaction with the enrichments, with certain enrichments (perches and novel objects) more successful at reducing pecking than others (scattered straw and scattered grain) (Crowe & Forbes, 1999). Martrenchar et al. (2001) also found significant reductions in wing, tail and head injuries when straw and objects were added to the pens of young male and female turkeys, although provisions of perches had little effect.

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4. AIR AND LITTER QUALITY

CONCLUSIONS

1. **Air and litter quality can be impacted by dust, humidity, temperature and ammonia.**
2. **High temperatures, low humidity, and high ventilation increase the amount of airborne dust. Small dust particles are deposited in the lower airway of broilers which can irritate the airways and lead to an increase in lung related disorders.**
3. **Foot health and broiler mortality can be compromised at high temperature and humidity in combination with high stocking density. The specific combination of temperature, humidity and stocking density that impacts poultry meat birds varies with the size and species of bird.**
4. **Litter moisture can be affected by environmental conditions such as type of drinkers, humidity, ventilation rates and stocking density. Litter moisture is thought to be a major contributor to the incidence of foot pad dermatitis.**
5. **Ammonia is an irritant. Domestic fowl are able to detect it at 5ppm and concentrations greater than 25ppm can cause short-term damage to respiratory tissues and feet, and corneal ulcerations. Reductions in immune function may be observed at exposure levels below 25ppm.**

INTRODUCTION

Air and litter quality are closely intertwined with stocking density; however, in this report we have attempted to separate the two issues. In some cases, the reader may find further explanation in the *Stocking Density* section.

Measures for evaluating the welfare of broilers, broiler breeders and turkeys in regard to air quality and litter quality can include the biological function of the animals (health and productivity) and their affective state (subjective experiences). In terms of natural living, problems relating to air and litter quality are a consequence of indoor housing and are not a concern in natural habitats. Research to date has largely focused on:

1. In terms of biological functioning, studies have looked at production parameters, such as growth rate; measures of the stress response, such as blood or fecal corticosteroid concentrations; and health parameters, such as the occurrence of hock burn, foot and skin lesions, eye damage, respiratory health, and mortality.
2. In terms of affective states there has been little investigation; however, skin lesions and heat stress are thought to increase discomfort and pain. The aversiveness of gases has also been measured as an indicator of discomfort.

There are many types of air and litter contaminants that affect poultry, and often these contaminants are intertwined with one another, making it somewhat difficult to determine which factors are most problematic (de Jong et al., 2012).

DUST

Dust can significantly affect the air quality within a poultry production system (Lai et al., 2012; Takai et al., 1998). Dust in poultry houses originates from many sources including feed, feces, litter, feather debris and microorganisms (Lai et al., 2012; Takai et al., 1998). Madelin and Wathes (1989) examined dust microscopically and found that skin squames accounted for most of the dust particles throughout the growing period, although the amount from food and fecal debris increased with time. Down or feather fragments formed about 5% of dust particles. Environmental factors such as ventilation, feeding practices, bedding material and manure handling can all affect dust concentrations (Takai et al., 1998). Dust can be reduced by a number of methods, such as removing airborne dust by increasing the ventilation rate or reducing dust emission or generation from the sources (Takai et al., 1998). Misting systems are commonly used to limit airborne dust from the air in commercial houses. Oiling litter can be an effective means of reducing dust in broiler houses, although at concentrations above 16 ml oil/m^2/d adverse effects on foot pad quality were observed (de Jong et al., 2012).

Composition, concentration and size of the airborne particles are all important characteristics of dust and the effect that they have on air quality. Present within dust particles are pathogenic bacteria, viruses, endotoxins and other substances (Takai et al., 1998). Ammonia and odours can also be absorbed by dust particles, and dust has been implicated in transporting and magnifying odours (Takai et al., 1998).

Airborne particles are often classified by size; smaller than 10µm (coarse dust), smaller than 2.5µm (fine dust) and smaller than 1.0µm (Lai et al., 2012). Particles between 1µm and 10µm are the most prevalent size (more than 90%) in poultry barns (Lai et al., 2012). Particles with a diameter of approximately 1.1 µm are deposited most often in the lungs, abdominal and post-thoracic air sacs of chickens; greater numbers of larger (diameter of 3.7-7µm) and smaller (diameter of 0.3µm) particles are deposited in the anterior portion of the respiratory system, with smaller particles traveling deeper than larger particles (Collins & Algers, 1986). Most particulate matter (around 94%) in commercial Texas broiler houses was large enough to be captured by the upper respiratory systems before being inhaled into the lungs (Redwine et al., 2002). These larger particles will often be deposited in the nose and eyes while small particles are distributed throughout the respiratory system (Corbanie et al., 2006). Aerosol experiments have found that 5µm is an accurate cut-off point for deposition in the upper or lower airways of 2-week old broilers, whereas for 4-week-old broilers, the cut-off is increased to 10µm due to the increased airway diameter (Corbanie et al., 2006). An exception to this is 1-day-old chicks, which have been found to have a high number of particles greater than 5µm in the lower respiratory tract. This is thought to be due to the occurrence of mouth breathing and peeping performed by the young birds, which allows more particles to reach the lower airways (Corbanie et al., 2006). High ammonia concentrations can also damage the cilia of the mucocilliary apparatus and interfere with the ability of the bird to clear bacteria and dust from the lungs (Nagaraja et al., 1983).

Environmental factors and their impact on dust: Lighting programs have a clear relationship with dust concentration in poultry barns; during the light period, dust concentrations have been found to be about 4 times higher than during the dark periods (Calvet et al., 2009). High temperatures also affect dust levels. In rooms kept 2°C higher than the normal production temperature from weeks 3 to 7, significantly higher inspirable dust levels were found than in rooms kept at normal levels (Al-Homidan, 1998).

Ventilation rates also impact the concentrations of dust present in poultry barns. Ventilation will remove accumulated dust, but also makes dust on surfaces become airborne (Calvet et al., 2009). Ventilation rates are related to humidity levels; a reduction in the ventilation rate (in the winter, for example) generally leads to higher humidity and therefore lower dust levels. Conversely, other authors have suggested that because winter ventilation rates are much lower than summer in order to conserve heat, dust concentrations could be higher in the winter (Takai et al., 1998). Dust concentrations are lower in barns with wet floors and/or high humidity which helps bind the dust particles together (Takai et al., 1998).

Litter was found to contribute minimal direct amounts to airborne dust and act mainly as a reservoir (Madelin & Wathes, 1989). Bedding binds dust when it is wet, but fine bedding can contain small particles, and poor quality bedding (i.e. mouldy or weathered) can increase the dust levels (Takai et al., 1998). Birds scratching and moving in the litter also distributes particles through the air (Madelin & Wathes, 1989). Redwine et al. (2002) found that total suspended particulate concentrations increased with bird age, and Calvet et al. (2009) found a positive interaction between dust concentration and bird weight and activity index. A major increase in dust concentrations during the light period at about 20 days of age was also found by Calvet et al. (2009).

Impact of dust on biological functioning: Dust can be considered a health hazard through ways identified by Harry (1978) and summarised by Carpenter et al. (1986). When inhaled, dust can irritate the respiratory tract, which can lower the resistance to respiratory diseases. Dust can act as a carrier of non-pathogenic bacteria, or more importantly, pathogens. The number of airborne bacteria increased rapidly during the first 4 weeks of rearing, with staphylococci being the predominant species throughout the growing period (Madelin & Wathes, 1989).

Dust induces mild to severe hyperplasia of bronchiolar epithelium and mucous gland cells (Carpenter et al., 1986). These changes were similar to those seen in normal broilers which exhibit no apparent clinical disease. Parabronchioles were often altered by exudates within the lumen and heavy peripheral mononuclear infiltration. Lymphoid foci were more discrete in lungs of birds breathing filtered air and more diffuse in those breathing unfiltered air. Broilers reared in filtered air had twice as much structural change and lymphocytic reaction in their lungs compared to broilers reared in isolators which are relatively dust-free. Those reared in unfiltered air had 3 to 4 times the reaction, and the authors indicated that commercially raised birds were expected to show 10- to 20-fold increases in lesion severity.

Damage has also been found to the atria due to dust, with expansion and often fusion of the atria (Carpenter et al., 1986). Physical stress imposed on the lungs may have been responsible for spiral muscles in the walls of the atria. Infection in the lungs reduces the oxygen transfer, which can also lead to ascites in broiler chickens (Issac et al., 2010). A reduction in dust through air filtration lessens the severity of structural and lymphocytic reaction in the lung tissue of the birds (Carpenter et al., 1986).

RELATIVE HUMIDITY (RH)

Relative humidity in barns is affected by numerous factors including outside humidity, number, type and management of drinkers, density, size and age of birds, temperature and ventilation (de Jong et al., 2012). Health and mortality are affected by both temperature and RH present within a barn. However Jones et al. (2005) reported that RH was rarely monitored or controlled by production companies. At high stocking densities, the extent that broiler health was maintained was associated with keeping the temperature and RH within the recommended limits (Jones et al., 2005). High humidity and temperature, and the percentage of time these variables were out of the ranges recommended by the breeder companies affected conditions such as foot pad dermatitis, impaired gait, angle-in deviation, mortality and corticosteroid levels (Jones et al., 2005). Low humidity can also impact health. For example, RH levels lower than the recommended 50% in week 1 of the production cycle was associated with poorer gaits in week 6 (Jones et al., 2005).

<u>Impact of relative humidity on biological functioning:</u> The percentage of broiler chickens which died over the growth period was positively correlated with high humidity and temperature from weeks 3 to 5 (Dawkins et al., 2004). Mortality was also lower in summer than in winter (Dawkins et al., 2004), when ventilation rates were reduced in order to conserve heat within the barn, and may have led to higher humidity and temperatures within the barn.

LITTER QUALITY

Litter quality is directly related to moisture. Dawkins et al. (2004) found that 56% of the variation of litter moisture could be explained by design attributes such as heater position and number of drinkers per thousand birds. Litter moisture can also be affected by variables such as the type of drinkers provided, humidity, season, ventilation, consistency and amount of fecal material, and stocking density (Berg, 2004; Shepherd & Fairchild, 2010). Different types of litter have different absorption qualities which can lead to differences in the wetness of the litter (Mayne, 2005).

Although low litter moisture increases dust levels, litter wetness had been implicated as the primary cause of foot pad dermatitis (de Jong et al., 2012). Fine particle litter shows evidence of lowering the incidence of foot pad dermatitis. Small cup drinkers, diets that have higher digestibility, a temperature and humidity combination that prevents condensation, and lower stocking density are factors which Mayne (2005) suggests can help to keep litter moisture low.

Impact of litter moisture on biological functioning: Litter moisture has been positively correlated with dirty foot pads, legs scored as angle-out and with blemished hocks of broiler chickens (Dawkins et al., 2004). A retrospective study found that foot pad lesions and black hock burns at slaughter were higher in flocks reporting wet, fatty, sticky and/or crusty litter (Allain et al., 2009).

Foot pad dermatitis is a significant problem in turkey production and the incidence is thought to be impacted by many factors (Shepherd & Fairchild, 2010). Wet litter has a significant impact on the development of foot pad dermatitis, with birds exposed to clean, wet litter developing evidence of foot pad dermatitis as little as one week after exposure (Youssef et al., 2011). Litter wet with water and either ammonia or uric acid did not induce greater levels of foot pad dermatitis than litter wet with water only, indicating that it is the moisture rather than contaminants in wet litter that affect foot pad health. The severity of foot pad dermatitis, measured through external scores, increased with the number of days which the turkeys were exposed to wet litter, but histological scores did not (Youssef et al., 2011).

AMMONIA

Ammonia is an irritant, but does not cause drowsiness, unlike molecules such as carbon monoxide (Wathes et al., 2002). Ammonia may affect the mucus membranes of the eyes and respiratory tract, as well as the acid-base balance of the blood and olfactory and gustatory systems (Wathes et al., 2002).

Ammonia concentrations increase as broiler chickens grow (Madelin & Wathes 1989; Redwine et al., 2002). Wet litter conditions speed up the process of ammonia release from litter (Nagaraj et al., 2007). Diet has an important influence on the composition of excreta and therefore the litter. Reducing the crude protein and phosphorous content of the diet leads to lower nitrogen and phosphorous content of the litter, but no effects were found on ammonia concentrations, litter moisture or the pH of the litter surface (Ferguson et al., 1998).

Nearly 75% of the variation in air ammonia could be explained by ventilation type and season (Dawkins et al., 2004). Winter concentrations are noted to be higher than those found in summer, corresponding to the lower ventilation rates in winter (Redwine et al., 2002). However, ammonia concentrations measured over a 24 hour period in both summer and winter in commercial broiler barns housing 12000-14000 birds in the United Kingdom have been found to exceed 40ppm during periods in the winter (Wathes et al., 1997).

High concentrations of ammonia in the air, as well as high litter moisture, causes stress as measured using fecal corticosteroid (Dawkins et al., 2004). The variation in fecal corticosteroid in broiler chickens could be explained largely by temperature in the first week, humidity in the fifth week and season and ventilation type (Dawkins et al., 2004). Corticosteriod concentrations were also lower in summer than in winter, although overheating can happen in the summer and should be considered a potentially stressful event.

Impact of ammonia on biological functioning: Ammonia is thought to be related to bird health. Nagaraja et al. (1983) found that prolonged exposure to air ammonia concentrations of 10 and 40ppm resulted in excessive mucous production, matted ciclia and deciliation of the tracheal tissues of turkeys whereas the tracheal tissues of controls not exposed to ammonia appeared normal. In contrast Beker et al. (2004) found no difference in lesions scores in tracheal and pulmonary tissues of broiler chickens exposed to 0, 30 or 60ppm ammonia from days 1 to 21. In another report, lung, tracheal and air sac tissues of broilers exposed to aerial ammonia concentrations of 0, 25, 50 or 75ppm from days 1 through 28 did not show signs of inflammation when examined at 49 days (Miles et al., 2006). These authors suggested that because ammonia is highly soluble in water, it can be efficiently removed by mucous membranes of the upper respiratory system.

Ocular health is another concern associated with ammonia levels. Corneal lesions develop after exposure to ammonia concentrations greater than 25ppm, with greater effects at higher concentrations (Olanrewaju et al., 2007). Broiler chickens reared in ammonia concentrations of 25, 50 and 75ppm from 1 to 28 days of age showed corneal lesions at 14 days of age and some birds at 50 or 75ppm had corneal ulcerations, whereas birds kept at

25ppm had less extensive damage than those at 50 or 75ppm (Miles et al., 2006). After subsequent exposure to a commercial-like setting with no additional ammonia, healing of the eye lesions was seen. Clinical keratoconjunctivitis and anterior uveitis was also observed in birds exposed to 50 and 75ppm of ammonia for one week, whereas birds exposed to 25ppm showed no signs of anterior uveitis (Miles et al., 2006). In birds exposed to 75ppm of ammonia, keratitis was observed after one week; similar severity of keratitis was observed in birds exposed to 25ppm after three weeks. Ammonia concentration interacts somewhat with lighting intensity; decreasing light intensity intensified the results of the ammonia concentration (Olanrewaju et al., 2007), possibly due to increased contact time with litter.

Birds reared at more than 25ppm of ammonia had reduced weight gains compared to those reared at lower concentrations (Miles et al., 2004). While Beker et al. (2004) did not find significant effects on growth rates, the gain:feed ratios of broilers exposed to 60ppm ammonia were significantly lower than those of birds exposed to 0ppm with birds exposed to 30ppm being intermediate. Impairments in growth and feed utilization caused by ammonia exposure may be due to reductions in development and function of the small intestine and to reductions in intestinal defence mechanisms (Wei et al., 2012). In support of this, Wang et al. (2010) also found that immunoglobulin levels were reduced at 13ppm, antibody titers to Newcastle disease were reduced at 26ppm whereas growth rates of broiler chickens were reduced at 52ppm compared to controls (0ppm).

Foot pad dermatitis is an ulcerative condition that affects the plantar surface of the feet. Hockburn is the same condition except that it occurs on the hock as opposed to the feet. The indicative lesions are thought to be caused by tissue trauma due to the chemical burning effect of ammonia from urea in the litter (Berg, 2004). At air ammonia levels ranging from 1.3 to 29.8ppm, higher ammonia concentrations were correlated with more dirty pads and fewer birds with unblemished hocks (Dawkins et al., 2004). Foot pad condition was better in the summer than the winter, with more birds having a gait score of zero and fewer birds having dirty pads (Dawkins et al., 2004), possibly due to increased ventilation causing lower RH and ammonia concentrations. Hockburn was not correlated with ammonia concentrations or litter scores, but foot pad dermatitis was correlated with both measures (Haslam et al., 2006).

A clinical investigation of over 11000 turkeys in 66 flocks in Germany found foot pad dermatitis was widespread among turkeys (Krautwald-Junghanns et al., 2011). At 16 weeks of age, the incidence in turkey hens nearly doubled that of turkey toms. Consistent changes across age groups were noticeable within flocks but not between flocks, suggesting management and/or environmental causation. Investigations from the same study revealed that at slaughter only 2.1% of male turkeys and 0.6% of female turkeys had foot pads free of lesions.

Litter amendments: Treating litter with chemical compounds such as aluminum chloride, ferrous sulfate or alum can reduce the atmospheric ammonia production up to 97% (Do et al., 2005), with reductions in ammonia volatization mainly due to declines in litter pH (Choi & Moore, 2008a). Ferrous sulfate, although effective at reducing atmospheric ammonia, leads to an increased mortality rate, particularly in birds under 21 days of age due to iron toxicity (Do et al., 2005). Litter moisture content was also reduced with the addition of ferrous sulfate or aluminum chloride (Do et al., 2005). Choi and Moore (2008b) recommended an application rate of aluminum chloride of 200g/kg or less because this rate was effective at improving environmental parameters without the reduction in feed intakes and signs of lameness that were noted at an application rate of 300g/kg litter.

CARBON DIOXIDE (CO_2)

Ambient CO_2 concentrations have been measured at 400ppm (Purswell et al., 2011). Carbon dioxide remained constant throughout the growing period (Madelin & Wathes, 1989); however, it was higher in winter than summer, likely due to the reduction in ventilation (Wathes et al., 1997). Ventilation rates to control moisture have been found to maintain CO_2 concentrations at reasonable levels (Purswell et al., 2011). Carbon dioxide concentrations were not affected by the type of floor, deep litter or raised netting (Madelin & Wathes, 1989).

Impact of carbon dioxide on biological functioning: Growth performance was not affected by CO_2 levels up to 6500ppm during the growing period (Purswell et al., 2011). Carcass data was also not impacted by different CO_2 levels.

BIRDS' ABILITY TO DETECT NOXIOUS GASES

Birds have specialized chemosensory mechanisms within their olfactory systems and beaks that allow them to detect some noxious gasses. A common response to delivery of ammonia, carbon dioxide or hydrogen sulphide was an interruption of ongoing behaviour, and at the end of the delivery, birds oriented towards clean air delivery. These responses demonstrate the ability of domestic fowl to detect and respond to gaseous stimulation (McKeegan et al., 2005).

Laying hens are able to detect and show behavioural changes when ammonia is present at 5ppm in a test apparatus (McKeegan et al., 2005). Struggling, eye shutting and blinking were observed at 20ppm. High concentrations of ammonia have been correlated with higher fecal corticosteroid concentrations in broiler chicken houses, but at what level this response occurs has not been investigated (Dawkins et al., 2004).

Behavioural responses of laying hens suggest that domestic fowl can detect CO_2 concentrations of 10ppm as shown by mandibulation (beak opening) and interruption of feeding (McKeegan et al., 2005). Wathes et al. (1997) found that CO_2 concentrations ranged between 750 (0.075%) and 3500ppm (0.35%) in commercial broiler houses in the UK. Behavioural responses to concentrations of carbon dioxide that occur within poultry houses have not been examined and most research is focused on using the substance for euthanasia.

PREFERENCES/AVOIDANCE OF DIFFERENT GASES

While birds do not show immediate aversion to high ammonia concentrations, avoidance tests have shown that domestic fowl spend less time in environments with ammonia concentrations of 20ppm or greater (Jones et al., 2005). Broilers show a delayed aversion to higher concentrations of ammonia (Wathes et al., 2002). Less than half of birds exposed for about 30 seconds showed avoidance to ammonia (McKeegan et al., 2005). Broilers showed motivation to seek fresh air after thirty minutes of exposure to 40ppm of ammonia (Jones et al., 2003); the authors expect that the delay is due to a gradual development of a sense of malaise, which then motivates the animal to seek fresh air (Wathes et al., 2002).

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5. STOCKING DENSITY

CONCLUSIONS

1. **As stocking density increases, poorer measures in biological functioning (e.g. weight gain, injuries, gait scores) are observed on an individual bird level. The effects are generally linear with no clear cut-offs for the different measures.**
2. **Environmental conditions (e.g. temperature, relative humidity, air and litter ammonia) are significantly affected by stocking density.**
3. **Broiler chickens prefer to lie near feeders and drinkers but will increasingly choose to rest away from the feeders as stocking density increases. As stocking densities increase, birds are jostled more frequently and resting is disturbed more often.**
4. **Management has a major impact on bird welfare especially at higher stocking densities.**

INTRODUCTION

Measures for evaluating the welfare of broiler chickens, broiler breeders and turkeys in regard to stocking density can include the biological function of the animals (health and productivity) and their affective state (subjective experiences). In terms of natural living, problems relating to stocking density are not a concern in natural habitats, but behaviour and preferences of the birds can be examined to give an indication of their natural spacing behaviour. Research to date has largely focused on:

1. In terms of biological functioning, studies have looked primarily at growth, as well as other production parameters, such as leg health, injuries and mortality.
2. In terms of affective states, preference tests have been used to allow birds to indicate what density they would prefer, but research has mostly overlooked the subjective experiences of the birds.
3. For natural living, research has begun to examine the behaviours of the birds in high and low stocked houses or pens, giving an indication of the natural spacing behaviour, but the impacts of stocking density are not a concern in natural habitats.

There have been several recent reviews of the research on the effects of stocking density on the welfare of broiler chickens (Estevez, 2007; de Jong et al., 2012). As the number of birds per unit of space increases, higher returns can be achieved. These increased densities driven by economic returns may come at the cost of reduced performance, health and welfare of individual birds; however, at what point this occurs is not always the same and depends on many factors. Setting limits for stocking densities is difficult, as described by (Estevez, 2007):

1. Health and welfare decrease progressively with increasing density, so it is difficult to set a limit on what is acceptable and beyond which point it is unacceptable.
2. Different limits can be determined by using different measurements.
3. Housing conditions and management have a large impact on animal welfare, independent of density.
4. Different genetic lines may require different limits.
5. Scientific studies may not be adequate or may not accurately represent commercial conditions.

Because it is difficult to determine clear limits, current guidelines vary widely on what the maximum density should be. Guidelines currently range from about 31.7kg/m^2 to 41.5kg/m^2, depending on final body weight and country or organization which makes the recommendation (Estevez, 2007).

Research relating to stocking density can be done through either changing the group size in a given area or changing the area for a given group size. Commercially, the former is much more likely to occur, as it is more practical to increase or decrease the number of birds placed in a barn than it is to change the size of the barn.

Scientific research on the other hand can utilize either method of manipulating the stocking density for a group of birds. Often scientific experiments are also performed on relatively small groups compared to commercial operations. It is possible that some of the effects of stocking density are altered due to these limitations. Stocking density is also reported in a variety of units. An attempt was made to convert these units to kg/m^2 wherever possible in order to allow for comparison across studies. The effects of stocking density on performance and mortality from a number of studies are summarised in Table 1.

IMPACT OF STOCKING DENSITY ON PERFORMANCE

Increasing stocking density usually increases the monetary return per unit of area, but generally the return per bird decreases due to reduced growth rate (McLean et al., 2002). A large-scale study including 2.7 million broiler chickens showed a linear decrease in growth rate as stocking density increased from 30kg/m^2 to 46kg/m^2 (Dawkins et al., 2004). Puron et al. (1995) determined that increasing the stocking density of male broiler chickens higher than 42.1kg/m^2 and females higher than 40.1kg/m^2 did not increase the kg of broiler produced. Puron et al. (1995) also found a linear decrease in live weight and feed consumption as the space per bird decreased. In other results, broilers reared at 28.6kg/m^2 were larger than those reared at higher or lower stocking densities (Feddes et al., 2002). Body weight gain and final body weight were also lower for birds reared at 39.9kg/m^2 compared to 29.9kg/m^2, likely due to decreased feed consumption found in more dense pens (Onbaşilar et al., 2008). Body weight, as measured at 28 and 42 days of age, decreased as stocking density increased, and again, feed intake per bird was lower in higher stocked pens (Tong et al., 2012). Broiler chickens reared at 30.2kg/m^2 were heavier than those reared at 36.6kg/m^2 at 43 days of age, but the litter and lighting regimens also differed between these groups, so it is unclear if stocking density was the sole cause of this difference in growth (Meluzzi et al., 2008). Turkeys also had reduced growth at higher stocking densities, with weight consistently lower at about 50-57kg/m^2 than at about 34-36kg/m^2 (lower stocking density between 12 and 15 weeks of age) (Martrenchar et al., 1999).

Although high stocking densities have been well documented for reducing growth rate in broiler chickens, the results are not always duplicated. McLean et al. (2002) found no effect of density on weight gain in broiler chickens reared at 28.2, 33.5 or 38.5kg/m^2. Similarly, Ravindran et al. (2006) found no effect of stocking density on weight gain or feed intake over a 35-day trial using densities of about 34, 42 and 50kg /m^2 and Thomas et al. (2004) found faster weight gain in broiler chickens reared at 9.6kg/m^2, but no difference in broilers reared at 17.8, 27.6 or 35.8kg/m^2. A large body of evidence indicates that differences in growth are due at least partially to husbandry and environmental factors, and thus the stocking density itself does not produce consistent results.

The impact of stocking density on growth appears to differ with the sex of the bird as well. High stocking density (42kg/m^2) affected male broiler chickens more by 35 days of age, whereas females were more affected from 36 to 42 days of age by high stocking density (42kg/m^2) (Zuowei et al., 2011).

Feed intake during the final week was significantly lower in birds reared with a target final density of 40kg/m^2 compared to those reared with a target of 28kg/m^2 and those reared at 34kg/m^2 had an intermediate intake (McLean et al., 2002). Feed conversion was not found to differ with stocking density in various reports ranging from 23 to 51kg/m^2 (Feddes et al., 2002; McLean et al., 2002; Puron et al., 1995; Ravindran et al., 2006). Water consumption increased with increased stocking densities (Feddes et al., 2002).

Table 1: A summary of production results found in studies comparing various stocking densities.

Reference	Sex of birds	Space allowances compared (kg/m^2 at depopulation)	Body weight (g at depopulation unless specified)	Mortality (%)	Feed Intake (g/bird)
Puron et al., 1995†‡	Male broiler chickens	24.2 28.0 31.6	2604 2544 2453	6.74 7.68 8.21	5200 5016 4933
		33.5 36.0 37.6	2509 2517 2486	4.73 4.67 5.40	5260 5264 5167
		41.5 42.1 42.5	2588 2684 2528	8.28 7.64 6.67	5172 5229 5014
	Female broiler chickens	22.8 26.3 30.0	2196 2119 2096	4.89 4.61 4.74	4522 4336 4308
		30.3 32.5 34.5	2132 2102 2102	4.00 4.69 3.53	4635 4584 4585
		37.1 40.1 40.2	2183 2238 2164	5.68 5.77 7.15	4369 4525 4351
Feddes et al., 2002 †‡	Female broiler chickens	22.9[a] 28.6[a] 34.6[a] 46.0[a]	1915 1995 1931 1898	1.7-5.3	2993 3183 3068 3003
Onbaşilar et al., 2008 †‡	Male broiler chickens	29.9* 39.9*	2513 2279	Not reported	3828 3511
Tong et al., 2012 †‡	Male broiler chickens	14.5[a] 19.5[a] 24.2[a]	1172 1139 1100	1.33 -2.34	2435* 2259* 2150*
Meluzzi et al., 2008 †‡¶	Male broiler chickens	30.2 36.6	2792 2713	1.61 3.20	4739* 4524*
McLean et al., 2002 ‡	Male and female broiler chickens	28.2 33.5	2492g gained 2467g gained	No effect of density	4163 4086

Reference	Sex of birds	Space allowances compared (kg/m^2 at depopulation)	Body weight (g at depopulation unless specified)	Mortality (%)	Feed Intake (g/bird)
		38.5	2398g gained		3994
Ravindran et al., 2006	Male broiler chickens	33.1-34.7 42.2-43.0 49.8-50.7	2028-2124 2065-2108 2033-2072	1.19-3.63	2940-3033 3033-3088 3051-3082
Hall, 2001¶	Mixed sex broiler chickens	33.1, 33.2, 34.4, 34.2 38.1, 38.0, 39.2, 40.1	1820-2170 1790-2180	6.4 7.0	Not reported
Thomas et al., 2004 †‡	Male broiler chickens	9.6 17.8 27.6 35.8	1886g gained 1740g gained 1796g gained 1747g gained	0.9 1.3 4.3 3.8	3230 3016 3085 4057
Zuowei et al., 2011 †‡	Male broiler chickens	26.0 42.0	2599.8-2679.6* 2746.8-2847.6*	3.3	4674.6-4767.0* 4712.4-4775.4*
	Female broiler chickens	26.0 42.0	2163-2179.8* 2268-2326.8*	1.1	4019.4-4179.0* 3990.0-4086.6*
Martrenchar et al., 1999 †	Female turkey broilers to 12 weeks of age	38.8, 40.3* 48.9, 51.6* 60.1, 62.7*	6206, 6450 6018, 6348 6008, 6271	2.0-5.6	Not reported
	Male turkey broilers to 12 weeks	33.5, 36.2* 42.3, 46.1* 52.4, 56.6*	8032, 8678 7826, 8526 7859, 8487	2.0-5.6	Not reported
	Male turkey broilers 12 to 16 weeks	33.7, 33.5* 41.5, 42.2* 49.7, 52.4*	13488, 13387 12874, 13073 12414, 13087	2.0-5.6	Not reported

* Represents a measurement converted from the original paper.
[a] Indicates densities adjusted for mortality.
† Indicates the study found significant differences in body weight due to stocking density.
‡ Indicates the study found significant differences in feed intake due to stocking density.
¶ Indicates the study found significant differences in mortality due to stocking density.

IMPACT OF STOCKING DENSITY ON MORTALITY

Mortality may be impacted by stocking density. Broiler chickens reared with final target densities of 28 to 40kg/m^2 did not differ in overall mortality rates (McLean et al., 2002). Mortality was not different between broiler chickens housed at stocking densities of 46.0, 34.6, 28.6, and 22.9 kg/m^2 (Feddes et al., 2002) or between turkeys housed at calculated densities of 34-39, 42-52, or 50-63kg/m^2 (Martrenchar et al., 1999). In contrast, Hall (2001) found that broiler chickens reared with a target final stocking density of 40kg/m^2 had a higher daily mortality rate late in the rearing period as compared to those raised to a target of 34kg/m^2. A higher number of broiler chickens were also culled for leg problems in the higher stocking density late in the rearing period (Hall, 2001).

IMPACT OF STOCKING DENSITY ON CARCASS CHARACTERISTICS

Stocking density can impact some of the carcass characteristics of birds. At high stocking densities, birds may climb over one another, causing scratching and bruising, but the effect of stocking density on carcass grade, contamination and condemnation was minor (Feddes et al., 2002). Bruising on wings and legs was higher in birds stocked at a final target density of 40kg/m^2 compared to 34kg/m^2 (Hall, 2001). Breast blisters and hock burn were also higher at greater densities, possibly due to decreased activity and/or wet litter. In contrast, McLean et al. (2002) found no effect of stocking density on hock scores, and scores were low overall. Carcass weight and quality (e.g. breast yield, abdominal fat yield, shear force and water loss rate) were not impacted by stocking density (Ravindran et al., 2006; Tong et al., 2012). In turkeys, density was not related to blisters in one experiment, but was related in another, with more male turkeys reared at 33.5-36.2kg/m^2 having no lesions than those reared at 49.7-56.6kg/m^2 (Martrenchar et al., 1999). Scratches and scabs on the feet and hips of turkeys were higher at the highest density (Martrenchar et al., 1999).

IMPACT OF STOCKING DENSITY ON FOOT AND LEG HEALTH

Foot pad and hock lesions were more frequent in broiler chickens kept in groups stocked over 40kg/m^2 than in groups under 30kg/m^2 (Ventura et al., 2010; Zuowei et al., 2011). Gait scores (0 being normal gait, 2 being severe impairment of walking ability) were also higher in broiler chickens raised in 42kg/m^2 pens compared to 26kg/m^2 pens (Zuowei et al., 2011). In a large-scale commercial study, a linear increase was found in the percentage of birds with a gait score of 0 (normal walking ability) with decreasing stocking densities (Table 2) (Dawkins et al., 2004). High stocking density related to poorer gait scores in turkeys, particularly in females (Martrenchar et al., 1999).

Table 2: Gait scores, jostle and growth rates for each stocking density (Adapted from Dawkins et al., 2004).

	30 birds/m^2	**34 birds/m^2**	**38 birds/m^2**	**42 birds/m^2**	**46 birds/m^2**
Percentage of birds scoring gait score 0	80.8	74.2	76.1	68.0	61.1
Jostle incidents per minute	0.316	0.431	0.455	0.566	0.618
Growth rate (g/day)	50.3	49.9	49.7	48.8	47.7

IMPACT OF STOCKING DENSITY ON ENVIRONMENT (HUMIDITY, LITTER QUALITY, AIR QUALITY)

In a large-scale study involving 10 commercial broiler companies in the U K and Denmark, Dawkins et al. (2004) found that stocking density was less important to the welfare of the birds than was control of the birds' environment. The study involved 2.7 million birds in 114 houses at stocking densities ranging from 30 to 46 kg/m^2. Differences in the effects of stocking density on measures of bird welfare were significantly less than the differences across companies. Although very high stocking density affects chicken welfare, within limits, it appears to be less important than other factors such as environment, nutrition and genetics (Dawkins et al., 2004).

Management factors that varied across companies and that appeared to significantly influence birds' abilities to cope with high stocking densities were mainly those which affected litter moisture and air ammonia (Dawkins et al., 2004). Higher levels of litter moisture and ammonia were correlated with more dirty pads, more legs scored as angle-out and fewer birds with no hock blemishes. Variation in fecal corticosteroid was explained largely by temperature, humidity, season, and ventilation type. As corticosteroid concentrations were correlated with mortality and mortality was also positively correlated with humidity and temperature during weeks 3-5, the authors suggested that stress on the birds and their risk of dying depends on the control of the environment. In a companion publication from the same study, Jones et al. (2005) reported that a significant amount of the variation in broiler chicken health and welfare could be accounted for by the amount of time that managers spent maintaining temperature and relative humidity at recommended levels. Key factors related to ventilation and air control that also varied significantly across companies included position of the heaters, number of drinkers per one thousand birds, season and ventilation type.

Although the Dawkins et al. study (2004) indicated that the environment in which the birds are living is more critical to their welfare than stocking density, the environment can be impacted by stocking density (de Jong et al., 2012). When stocking density increases, airflow at the bird's level is often reduced; this slows the dissipation of body heat through the air. As well, more birds mean higher humidity in the air through respiratory evaporation and fecal output. Increased stocking density results in more deep panting during weeks five and six (it was not seen in weeks one to four), with less deep panting seen in broiler chickens housed at 28.2kg/m^2 than at 33.5 or 38.5kg/m^2 (McLean et al., 2002).

Stocking more birds in a given area may also increase relative humidity; Jones et al. (2005) reported humidity at 6 weeks to be significantly lower for barns stocked at 30kg/m^2 than for barns stocked from 34 to 46kg/m^2. Stocking density has a significant effect on litter condition in broiler pens. Litter scores and litter moisture were significantly higher in pens stocked with final target densities of 40kg/m^2 compared to those stocked to 28kg/m^2 (McLean et al., 2002).

BEHAVIOURAL IMPACT AND NATURAL SPACE PREFERENCES

Spatial distribution amongst birds within a pen varies with stocking density. At low stocking densities, broiler chickens attempt to achieve a low treatment density and at high densities they attempt to minimise the disturbance by other birds (Arnould & Faure, 2003; Buijs et al., 2010), with the shift in behaviour begining at 33kg/m^2. Broiler chickens have been found to be unevenly distributed on the floor, even when reared at low density with available space (Arnould & Faure, 2003). When available space does not limit the choices, broilers prefer to lie near feeders and drinkers. Distribution of birds throughout available space seems highly related to the location of feed and water at a low density, but at a higher density, the birds stayed mostly in areas free of feeding and drinking equipment (Arnould & Faure, 2003). Difference between densities became more pronounced as the birds aged, and birds reared in densities from 33-56kg/m^2 showed a higher preference for the outer part of the pen than those reared at 6-23kg/m^2 (Buijs et al., 2010). This may occur because the birds are seeking cover and concealment (Cornetto et al. 2002), but is also thought to be more likely that birds are seeking areas with fewer disturbances in these highly stocked groups (Arnould & Faure, 2003). In contrast, Febrer et al. (2006) found birds did not attempt to get away from one another at stocking densities from 30 to 46kg/m^2, and appeared to cluster while resting or performing comfort behaviours. Using computer models generated from data on the amount of floor space used for different activities and synchronisation of behaviour patterns, Bokkers et al. (2011) determined that a stocking density of 39.4kg/m^2 should not be exceeded in order to allow free expression of behaviour in broiler chickens. There is some evidence from small-scale studies that use of vertical panels (Cornetto & Estevez, 2001) and barrier perches (Ventura et al., 2012) decrease disturbances amongst birds and promote more even use of pen space, but these have not been tested under commercial conditions.

The percentage of time spent lying was not influenced by stocking density, but the frequency of lying was greater at a target final density of 40kg/m^2 than 34kg/m^2 (Hall, 2001). Lying bouts of turkeys were terminated by disturbance more often at higher density of 52-62kg/m^2 compared to the lower at 34-39kg/m^2 (Martrenchar et al., 1999). Disturbances were also more common near the end of the rearing phase as target stocking densities were reached (Buijs et al., 2011; Hall, 2001; Martrenchar et al., 1999). Jostling was also found to increase with increasing stocking density from 30kg/m^2 to 42 and 46kg/m^2 (Febrer et al., 2006). This is not surprising as more birds per unit of area can lead to birds climbing over or bumping into others as they move across the pen.

Stocking density has not been shown to impact other behaviours such as feeding or drinking in broiler chickens at densities of 34 to 40kg/m^2 (Hall, 2001) or 28 to 40kg/m^2 (McLean et al., 2002) or in turkeys at 34-63kg/m^2 (Martrenchar et al., 1999). Percentage of time spent walking and standing, and position changes did not vary with stocking density ranging from 34 to 63kg/m^2 in turkey broilers (Martrenchar et al., 1999).

Introduced male turkeys were the target of aggressive behaviour (pecks, threats) whether they were introduced to a small or large pen containing 5 male turkeys, but more pecks and threats were performed in the small pens (Buchwalder & Huber-Eicher, 2004). If the bird was able to retreat a distance of 150cm, significantly less pecks to the head and neck occurred. For turkeys to be able to retreat this distance, they would need to be stocked at less than 1 bird/m^2 (Buchwalder & Huber-Eicher, 2004). This study focused on differing pen sizes as compared to stocking densities, per se, and it is possible that these results would differ in larger groups. Also, under commercial conditions birds would rarely be introduced to an established flock.

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6. LAMENESS

CONCLUSIONS

1. **Changes in gait in broilers and turkeys after administration of analgesics and anti-inflammatory drugs suggest that clinical lameness causes some pain. Changes in gait are also apparent but it is unclear if these changes are due to pain, conformational changes, or both.**
2. **Birds with poorer walking ability lie more and spend less time performing activities which require them to stand than birds with better walking ability.**
3. **Lameness is in most cases a multifactorial issue and the cause may be site and context specific. Despite these influences, older and heavier birds generally have more difficulty walking than younger and lighter birds. A threshold of 1.25 kg at 54 days has been determined for broiler chickens, where the birds became lamer the heavier they became.**
4. **Genetic selection causing increased growth rate and percentage of breast meat in broilers has altered the distribution of weight and increased the weight load on immature bones. These changes have led to altered gaits and leg pathologies.**

INTRODUCTION

Lameness is characterised by an abnormal gait and posture as well as impaired walking ability. Lameness in meat birds is complex and multifactorial. Combined effects of influences such as weight, skeletal integrity, nutrition, lighting program and disease influence the occurrence of lameness in meat birds. 'Lameness' and 'leg weakness' have been used to describe many disorders which can affect the skeleton, muscle, tendons, skin or nervous system and result in injury or defect that affects the walking pattern.

Measures for evaluating the welfare of meat birds in regard to lameness can include the biological function of the animals (health and productivity), their affective state (subjective experiences) and naturalness (the ability to express important behaviours). Research to date has largely focused on the pathology and causes of lameness.

1. In terms of biological functioning, studies have looked at some production parameters, mainly focusing on growth and morbidity. Lameness has an economically important impact in poultry production due to culling or death and production losses.
2. In terms of affective states, walking ability is often assessed. Moderate to severe lameness is assumed to be painful as suggested by improvements in gait following the use of analgesics.
3. The intense genetic selection of modern meat birds for fast growth and carcass conformation have been implicated as one factor in the occurrence of lameness.

Severe lameness affects the welfare of meat birds through leg pain and impaired walking ability (Bradshaw et al., 2002). Lameness in birds can result from infectious causes, which are less prevalent but may cause birds to become extremely lame, and non-infectiousness causes which include developmental, degenerative and metabolic disorders; these are more prevalent and lead to birds becoming immobilized to a lesser degree than infectious causes (Butterworth et al., 2003; Gentle, 2011).

The literature reviewed in this section is focused on recent reports, since the genetics of the birds and conditions which they are reared in changes frequently, thereby changing some of the problems and causes of lameness (Bradshaw et al., 2002).

GAIT SCORES

Gait scores were first introduced by Kestin et al. (1992). Generally, a bird is placed in a test pen or corridor and approached by an observer from behind until it begins to move and the movement is scored based on criteria described below. These scores are widely used to evaluate leg problems, with male birds scoring higher. These scores were modified slightly to improve objectivity by Garner et al. (2002). Birds with scores of 4 or 5 are rarely used in research due to ethical reasons and are generally culled on farms (Bradshaw et al., 2002).

Table 3: Modified gait scores, adapted from Garner et al. (2002).

Gait Score	Identifiable traits
0	No impairment, smooth locomotion
1	Detectable but unidentifiable abnormality, unsteady when walks but readily runs from observer
2	Identifiable abnormality but defect has minor impact on the birds' biological functioning. Often the bird makes short, quick, unsteady steps with one leg.
3	Identifiable abnormality that impairs the function of the bird. The bird will move away from observer when approached or touched but will not run.
4	Severely impaired function but still capable of walking.
5	Complete lameness, the bird cannot walk.

LAMENESS AND PAIN

Clinically lame poultry appear to endure pain when they walk. Treating birds with obvious gait abnormalities with a non-steroidal anti-inflammatory drug (NSAID) increased the speed and walking ability of birds and reduced gait scores (McGeown et al., 1999; Nääs et al., 2009). Similarly, turkey broilers treated with an analgesic (butorphanol) at 7 weeks of age spent significantly more time putting weight on their legs than control birds (Butchwalder & Huber-Eicher, 2005). Adult male turkeys treated with betmethasone, a steroid thought to reduce pain through action on the inflammatory processes, spent more time standing and walking than control turkeys (Duncan et al., 2001). Thus, by providing analgesic and anti-inflammatory effects, the birds' ability to move was improved. Lame broiler chickens also selected feed containing carprofen (an NSAID) more than sound birds and the amount of carprofen ingested increased with lameness (Danbury et al., 2000) which suggests a conscious perception of pain. Gait scores were reduced with the inclusion of an NSAID in the diet (Danbury et al., 2000). In contrast, Siegel et al. (2011) found that broiler chickens with gait scores of 2, 3 or 4 did not select feed containing carprofen.

Broilers with a gait score of 3 have been found to rest more and stand less than those with a gait score of 2 (Skinner-Noble & Teeter, 2009). Broiler chickens lie more as their walking ability deteriorates, and lame birds often lie with one leg extended at near right-angles to their body (Weeks et al., 2000). Broilers and turkeys which suffer lameness also spend less time in activities which require them to stand (Duncan et al., 2001; Skinner-Noble & Teeter, 2009), a behaviour which is consistent with suffering chronic pain while standing (Nääs et al., 2009). Walking also decreased in lame broilers and as the birds matured (Weeks et al., 2000). Broilers which were lame fed lying down almost half the time and this increased with age while time spent standing while eating decreased (Weeks et al., 2000).

Although behaviours displayed by lame birds can indicate pain, some differences in gait may be due to morphological changes associated with altered center of gravity due to large breasts and short legs compared to bodyweight. Conformational changes may result in alterations in locomotion that may not be painful (Corr et al., 2003b; Gentle, 2011). This is also supported by Seigel et al. (2011), where broilers with poor gait scores did not choose NSAID treated feed. Birds with gait scores of 2 and 3 have also been found to have similar heterophil: lymphocyte ratios, suggesting that there were no physiological stress differences between the two groups (Skinner-Noble & Teeter, 2009). Pathological differences were also absent in the sciatic nerve and surrounding muscle between the two gait scores (Skinner-Noble & Teeter, 2009). A more thorough understanding of the conditions that affect walking ability is needed to allow assessment of whether these conditions are painful (Gentle, 2011).

COMMON TYPES OF LEG DEFORMITIES

Leg deformities have unique and overlapping pathologies and causes. Valgus deformities, a common type of lameness in broilers, may be visible as early as 10 and 14 days of age (Randall & Mills, 1981). This deformity is caused by a lateral bending without twisting of the distal tibiotarsal extremity and the proximal tarsometatarsus (Randall & Mills, 1981). As the angulation of the two bones increases (knock-kneed), the tendon is eventually displaced and lies on the postero-lateral aspect of the intertarsal joint. Some birds will recover or improve before the tendon slips, but once the tendons become displaced, birds spend most of their time squatting, and death or culling is the norm (Randall & Mills, 1981). Bruising and subsequent infection on the posterior aspect of the intertarsal joint often accompanies tendon displacement as well (Randall & Mills, 1981). Varus deformity is caused by a medial deviation of the leg, and results in a bow-legged appearance if both legs are affected (Randall & Mills, 1981).

Dissection of adult male turkeys revealed mild or moderate valgus angulation of the intertarsal joints present in all birds (Duncan et al., 2001). Destructive cartilage loss, particularly antitrochanteric degeneration, was also common in turkeys and was most severe in hip joints (Duncan et al., 2001). Partial or total rupture of intra-articular ligaments in knee and intertarsal joints also occur in turkeys (Duncan et al., 2001).

Tibial dyschondroplasia (TD) is a skeletal disease which results from the uncoupling of growth plate chondrocyte proliferation during bone elongation and endochondrial ossification (Cook, 2000). This causes a mass of uncalcified cartilage in the proximal end of the tibiotarsus (and other long bones). Deficiencies in any number of water-soluable vitamins or manganese or zinc can lead to chondrodystrophy. Rickets and femoral head necrosis can also occur when bone mineralization is decreased (Cook, 2000). Rickets is noted to precede many pathological conditions including TD, osteomyelitis, femoral head necrosis and ascites in broilers (Dinev, 2012).

CAUSES OF LAMENESS

Lameness in broilers, broiler breeders and turkeys is generally a multifactorial issue, and is often site and context specific (Bradshaw et al., 2002). Nutrient toxicities, deficiencies and imbalances, genetics, pathogens, mycotoxins and management practices all affect skeletal growth and development (Cook, 2000). Feeding regimen, age and genotype have all been found to significantly affect the gait score in broiler breeders; however, a large portion of the variation was due to liveweight of the bird (Kestin et al., 2001) or age at which the bird was assessed (Knowles et al., 2008). In general, older (over 35 days of age) and heavier broilers have more difficulty walking and are given higher gait scores (Nääs et al., 2009). Kestin et al. (2001) found that a threshold existed at about 1.25kg at 54 days of age, where the birds become lamer the heavier they became, a phenomenon that was consistent across various genotypes (Kestin et al., 2001). Leg weakness is generally minor at 4 weeks of age, but gait scores deteriorate at about 0.45 gait score per week (Sørensen et al., 2000). Older broilers (28, 35 and 49 days of age) show significantly different peak vertical forces in each leg when measured with a force measurement platform system, perhaps predisposing the birds to lameness (Nääs et al., 2009).

Although feeding a diet with lower energy and protein density led to improvements in bone quantity and quality over broiler chickens of the same age fed a high energy and protein diet, improvements disappeared when birds of the same body weight were compared (Leterrier et al., 1998). Broilers fed a low density diet did have a lower incidence of bone deformities at 42 days of age, but also weighed less (Leterrier et al., 1998).

Other factors such as season (in the UK: September was worst, March best), the inclusion of whole wheat in the diet, increased hours of darkness, stocking density, antibiotic usage and the presence of dusty or broken pellets have also been associated with lower prevalences of leg disorders (Knowles et al., 2008).

Infectious causes: Infectious diseases can induce skeletal problems in broilers, broiler breeders and turkeys. The agents implicated include reovirus, *Mycoplasma synoviae,* retroviruses and *Staphylococcus aureus* and generally affect the soft tissue and joint space, not the skeletal system (Cook, 2000). *Staphylococcus aureus* is one of the primary infectious causes of bacterial chondronecrosis (femoral head necrosis or tibial necrosis) that have been isolated from leg bones of lame broilers (Butterworth et al., 2001). Recently, in Canadian flocks, *Enterococcus cecorum* has also been found to cause arthritis and osteomyelitis leading to lameness of large numbers of broiler chickens and broiler breeders (Stalker et al., 2010).

Physical causes: In some cases, lameness can be due to physical damage to the leg of the bird. In a broiler breeder flock, the introduction of new, aggressive males to an established flock was thought to result in rupturing of gastrocnemius tendons (Crespo & Shivaprasad, 2011). Chronic conditions which lead to damage of the tendon can predispose the tendon to rupture when put under increased stress from jumping onto the ground or over feeders and waterers.

Feeding regimens: Restricting feed can help to reduce some skeletal disorders, and if growth rate is decreased to a great extent, skeletal disease can be dramatically reduced. Restricting feed earlier, for longer durations and more severely have been associated with better walking ability and a lower prevalence of TD in broiler chickens (Su et al., 1999). While many of the effects seem to be linked to body weight of the birds, the prevalence of TD was reduced with earlier restriction, while starting restriction later was linked with better walking ability in the birds (Su et al., 1999).

Sequential feeding (feeding different diets over a period of 1 or 2 days) of broiler breeders improved the average gait score compared to control birds, but the occurrence of severe abnormalities did not differ (Leterrier et al., 2008). Sequential feeding acts to reduce early growth, which is thought to be a factor in leg abnormalities (Leterrier et al., 2008). Lower body weights lead to less stress on leg joints, and increased motor activity. By using sequential diets from days 8-28 of age, early growth was reduced while body weight at slaughter did not differ from controls (Leterrier et al., 2008).

Meal feeding has been investigated as a potential method of reducing leg weakness. Fewer meals per day have been associated with improved walking ability and less hock burn in broilers (Su et al., 1999). TD was higher in ad libitum birds than those fed meals as well (Su et al., 1999). Although fewer meals were associated with lower body weights, the effects on lameness was still evident when this factor was controlled and birds fed fewer meals had better a better food conversion ratio (Su et al., 1999).

Perches have also been investigated in the alleviation of leg weakness and TD, but the results are inconsistent, with some authors finding improvements in TD lesions (Tablante et al., 2003), and foot pad lesions (Ventura et al., 2010), while others found no impact (Mench et al., 2001; Su et al., 2000). The impact of perches needs to be further examined.

High dietary nitrogen concentrations have been implicated as a potential cause of foot pad dermatitis in turkeys, but recent research has suggested the primary cause of foot pad dermatitis is wet litter, thus high dietary protein is only relevant in so much as it increases water intake and thereby water expelled and litter moisture (Youssef et al., 2011a). High levels of soybean meal, potassium and oligosaccharides have some impact on the severity of foot pad dermatitis, but this effect is only seen on wet litter (Youssef et al., 2011b).

Environmental causes: The environment, particularly temperature and humidity in which the birds live undoubtedly affects their welfare, including leg and foot health. This is further discussed in the *Air & Litter Quality* section.

The environments in which the birds are incubated and reared also affect leg health. Broilers incubated in multistage machines (embryos at six different ages) had a higher percentage of crooked toes and gait scores of 1 or 2, while broilers hatched in single-stage machines had a higher percentage of gait scores of 0 (Oviedo-Rondón et al., 2009). Multistage incubators may provide a suboptimal environment during stages of incubation, particularly the later stages where high temperatures and hypoxia can affect bone development. The incidence of crooked toes suggested that males were more affected than females by incubation profile (Oviedo-Rondón et al., 2009).

There are many other factors which can affect lameness or leg weakness of meat birds. Some of these factors, namely litter quality, lighting and stocking density are addressed in those respective sections of this report.

GENETIC SELECTION

Meat birds have been heavily selected for fast growth and high levels of breast meat. Modern broilers fed *ad libitum* grew nearly twice as fast as their predecessors, with a higher percentage of body weight due to the pectoral (breast) muscle (Corr et al., 2003a). This rapid growth to high end bodyweights of the birds causes high loads on bones which are still immature, as well as an altered distribution of body mass changing the forces acting on the bones (Corr et al., 2003a). These morphological changes are suggested to cause gait pattern changes in order to improve stability during walking (Corr et al., 2003b). This altered gait appears inefficient and causes the birds to tire quickly, which may relate to low levels of activity seen in modern broilers, rendering the birds less capable of reaching feeders or drinkers (Corr et al., 2003b).

Growth rates and live weights of birds have been found to be a major cause of lameness in broiler breeders (Kestin et al., 2001). Selection for fast growth and heavy live weights has led to abnormally heavy weight loads being placed on relatively immature bones and joints of the birds. Fast-growing broilers had significantly higher incidences of TD and valgus deformities than their slow-growing counterparts (Shim et al., 2012). Birds with a gait score of 3 were heavier and had a more desirable breast conformation than birds with a gait score of 2, which may indicate that birds with a gait score of 3 are out of balance or front heavy (Skinner-Noble & Teeter, 2009). Birds with a gait score of 3 also had a greater breast angle than birds with gait score 2, while the percentage of breast yield was similar (Skinner-Noble & Teeter, 2009). Therefore, the ratio of mass to length appears to be related to differences in gait scores.

Comparisons of Giant Junglefowl and commercial broilers found that Junglefowl have greater force-generating capabilities and longer, faster-contracting muscles, both indicative of improved locomotor function but not necessarily joints that have larger ranges of motion (Paxton et al., 2010). Commercial broilers had larger abductor muscle mass and larger medial rotator mass than Jungle fowl, both which are related to hip joint support, although this varied across commercial lines (Paxton et al., 2010).

Differences in the prevalence and pathology of leg weakness between the major commercial lines of broilers existed and were examined by Kestin et al. (1999). Although there were differences between commercial lines in the prevalence of leg weakness, gait scores, TD, misshapen bones and legs and foot pad and hock burns, this research was performed more than 10 years ago and these differences may have shifted and/or disappeared.

Evidence indicates that there are differences at the genome level between sound broilers and broilers which become lame or are susceptible to lameness (Butterworth et al., 2003). Major breeder companies have identified certain causes of lameness and used genetic selection to control the incidence. The pathologies of lameness have therefore changed over recent times.

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7. LIGHTING REGIMENS

CONCLUSIONS

1. **Light intensity does not impact growth, feed conversion ratio or mortality levels of broiler chickens.**
2. **Light intensity influences behaviour. Broiler chickens reared under light intensities of 1 to 40 lux show less foraging and preening behaviours. Synchronization of behaviours exists under light intensities ranging from 1 to 40 lux, but appears to be stronger when birds are reared at 50 or 200 lux. Rearing birds at low light intensities could result in interrupted resting bouts and a lack of obvious resting and wakeful periods.**
3. **Broiler chickens and turkeys prefer bright light (200 lux) at 2 weeks of age. Although this preference is diminished by 6 weeks of age, bright light is still preferred for behaviours other than resting.**
4. **Daylength changes the timing of growth in broilers. Short daylength (such as 14 or 17 hours of light per day) slows growth early in life, but these birds display compensatory gain at older ages (after approximately 3 weeks of age) so that final body weights are equal or heavier than those of birds reared on long daylengths (for example, 20 or more hours of light per day). Feed efficiency is also improved in birds given periods of darkness. Time spent feeding is also highest in birds kept at 17 hours of light compared to those kept at 14, 20 or 23 hour daylengths.**
5. **Mortality increases with increasing daylength and leg abnormalities may also increase.**
6. **As daylength increases from 14 to 23 hours, broilers spend an increased amount of time during the light phase resting and less time standing, walking and running. Less time is also spent performing behaviours such as preening and dustbathing as daylength increases.**
7. **Rearing broiler chickens in blue or green light may improve some aspects of health and production but more research needs to be done on the welfare implications of monochromatic light.**
8. **There is very little research on lighting regimens for turkeys and often conclusions are conflicting.**

INTRODUCTION

Measures for evaluating the welfare of broiler chickens and turkeys in regard to lighting regimens can include the biological function of the animals (health and productivity) and their affective state (subjective experiences). In terms of natural living, problems relating to lighting regimens are a consequence of indoor housing where daylengths, intensities and light quality deviate considerably from those in the natural habitats in which poultry species evolved. Research to date has largely focused on:

1. In terms of biological functioning, studies have looked at some production parameters, such as the growth rate and feed efficiency, physiological processes, as well as parameters such as leg health and mortality.
2. In terms of affective states, the preferences of birds for light intensity to perform particular activities and daylength have been examined. The effects of light intensity on painful conditions and fearfulness have also been examined.
3. In terms of natural living, the diurnal activity patterns and behavioural time budgets of birds have been considered. In addition, behaviours such as dustbathing and preening are thought to indicate comfort and may not occur in birds that have poor welfare.

Vision is a very important sense in domestic poultry which evolved under natural light. Natural light is composed of both direct sunlight and diffuse light reflected from clouds and other surfaces (Prescott et al., 2003). Artificial light is a different quality than natural daylight; poultry houses are usually dimly lit, and the variation around the house may be large. Photoperiods may also be very different from those encountered in natural environments.

While artificial light is different than natural daylight, it may not be necessary to recreate the natural light environment in commercial settings. Prescott et al. (2003) suggest that the necessary criteria are those which poultry show a level of motivation for or that are essential for normal eye development. Thus, although differing from natural daylight, the artificial lighting programs may still meet the needs of poultry. The impact of the lack of natural light has not been well defined in scientific literature at this point.

There are many aspects of lighting which impact the welfare of poultry; light intensity, the duration of and distribution of light, as well as the properties of the light, such as wavelength, and source of light. Research has shown that intensity, duration and colour can impact the productivity, health and behaviour of the birds, along with the behavioural and physiological rhythms. These aspects also interact with one another to influence the welfare of the birds.

The brightness of light is referred to as light intensity. Brightness is measured in units of lux, which is equivalent to lumens per square meter. Other common measurements include foot candles, or clux. While lux and foot candles are based on the wavelengths within the human visual spectrum, clux corrects for the wider wavelength that poultry are sensitive to, and is dependent on initial irradiance (Lewis & Morris, 2006). Hence, lux and clux are not statically related. Light intensity is easily manipulated in modern indoor broiler production and can potentially affect welfare and productivity of the birds. It should be noted that research published to date has been conducted in small pen research settings.

There are two phases of light, the photoperiod or light phase and the scotoperiod or dark phase. There has been research into the duration of daylength in broilers, but it can be difficult to compare results between studies due to different programs tested, genotype and sex of the birds, as well as some differences in production techniques.

Light colour changes with wavelength, and includes violet (380-435nm), blue (435-500nm), green (500-565nm), yellow (565-600nm), orange (600-630nm) and red (630-790nm). Light emitted across the entire range of wavelengths is perceived as white light (Lewis & Morris, 2000). Before starting a discussion regarding light source impacts on poultry, it is necessary to understand that poultry have a different sensitivity to wavelength than do humans (Prescott & Wathes, 1999). They are sensitive to ultraviolet, short, medium and long wavelength light (Osorio et al., 1999; Prescott & Wathes, 1999).

LIGHT INTENSITY

Impact of light intensity on growth and feed conversion: Light intensity did not impact the weight gain, feed intake or feed conversion ratio from 0 to 35 days of age in broilers reared at 1, 10, 20 or 40 lux (Deep et al., 2010). Growth and feed conversion were also the same for broilers reared under 5, 50 or 200 lux (Mench et al., 2008).

Impact of light intensity on mortality levels: Total mortality or mortality due to any particular cause, including sudden death syndrome (SDS) did not differ among broilers kept at 1, 10, 20 or 40 lux (Deep et al., 2010). Similar rates of mortality were also found among birds at light intensities of 5, 50 or 200 lux (Mench et al., 2008).

Impact of light intensity on skeletal, foot and ocular health: No differences were observed in gait scores among broilers reared at 1, 10, 20 or 40 lux (Deep et al., 2010) or at 5, 50 or 200 lux (Mench et al., 2008; Blatchford et al., 2009), indicating that light intensity in these ranges had no impact on mobility. There was also no difference found postmortem in leg abnormalities such as calluses, torsion, pododermatitis, tibial dyschondroplasia or femoral erosions (Blatchford et al., 2009). Broilers reared at 200 lux had more leg bruising than others (corresponding with increased activity) but also fewer hock erosions (Mench et al., 2008; Blatchford et al., 2009).

As light intensity increased from 1 to 40 lux, the incidence of severe ulcerative painful foot pad lesions decreased (Deep et al., 2010).

Injuries in turkeys caused by pecking positively correlated with light intensity when 5, 10, 36 and 70 lux were compared (Moinard et al., 2001).

Larger and heavier eyes were found in broilers reared at 1 lux as compared to 10, 20 or 40 lux (Deep et al., 2010). Broilers reared at 5 lux also had heavier eyes than those reared at 50 or 200 lux (Mench et al., 2008). The research cited here could not determine if this is a welfare issue; however, the potential is there for larger eyes to cause pain by pressing on the optic nerve, and to possibly increase the incidence of eye diseases such as glaucoma. This could potentially affect broiler breeders and turkeys more than broiler birds since they are kept to older ages.

Impact of light intensity on melatonin concentrations: Serum melatonin levels were not affected by light intensity programs; all levels peaked during the dark period and were lowest during the light period (Deep et al., 2012). Under the intensities of 1, 10, 20 and 40 lux, flocks of broilers did produce melatonin in a significant diurnal pattern.

Impact of light intensity on behaviour: Broilers exposed to 17 hours of light and reared at 1 lux rested (inactively sitting on the litter) more than those reared at higher lux (10, 20 or 40 lux), although standing behaviour was not affected (Deep et al., 2012). Activity during the day was lower in broilers reared at 5 lux than those reared at 50 or 200 lux (Blatchford et al., 2009; Mench et al., 2008). Light intensity did not affect drinking and feeding behaviour by broilers but foraging behaviour was less prevalent in birds housed at 1 lux than others (Deep et al., 2012). In other results, broilers foraged more under 5 clux than 100 clux (Kristensen et al., 2007). Preening behaviour occurred at a lower proportion of time in 1 lux birds (Deep et al., 2012). Preening is considered to be a comfort behaviour in some cases, and the reduction indicates a potential concern for the welfare of the birds raised under low light intensities. Behaviours in turkeys varied with light intensity as well, where resting and perching occurred at higher frequencies under 1 lux photophase, while other behaviours (e.g. feedings, preening) were more common in brighter environments (Barber et al., 2004).

The percentage of time spent resting/sleeping and other behaviours (standing, feeding, drinking, etc.) during a 7 hour dark phase did not change among birds kept under light intensities of 1, 10, 20, 40 lux (Deep et al., 2012). During the photophase, birds kept at 5 lux had more total resting behaviour than those kept at 50 or 200 lux, but during the scotophase this trend was reversed (Alvino et al., 2009). During the scotophase, birds kept at 200 lux had the least number of resting bouts with the longest duration, whereas the 5 lux group had the most number of bouts with the shortest duration (Alvino et al., 2009). The number of interruptions occurred most often in the 5 lux group and least often in the 200 lux group. Birds kept at 5 lux appeared to spend more time in a passive wakeful state as opposed to a resting state and resting periods were dispersed throughout the day (Alvino et al., 2009). Birds kept at 50 or 200 lux showed obvious patterns of wakefulness and resting, with resting occurring more often during the scotophase (Alvino et al., 2009).

One reason for rearing broilers under low light intensity is to reduce the response of the birds to catching. This concern may be relevant, as broilers reared at 200 lux showed more wing flapping during a simulated catching at 1 lux than birds reared at 5 or 50 lux, which could result in injury during this time (Mench et al., 2008).

Impact of light intensity on behavioural diurnal rhythms: High light intensity may act as a more powerful zeitgeber (an external cue that synchronises an internal clock) than low light intensities. The diurnal rhythms of birds may not vary significantly among different low light intensities, but may differ from the rhythms observed in birds kept under high light intensities. Many behaviours occur in a similar diurnal fashion under light intensity treatments ranging from 1 to 40 lux during the photophase (Deep et al., 2012). However rhythms for preening, resting, eating and foraging behaviours of broiler chickens at high light intensities, i.e. 200 lux, appeared stronger than those at 5 or 50 lux (Alvino et al., 2009). Behavioural synchrony is particularly important for resting and sleeping. If resting bouts are synchronised, resting birds are disturbed less often by active flock mates, therefore allowing for longer resting bouts (Alvino et al., 2009).

Light intensity preferences: Preferences have been found for specific light intensities, and these preferences vary with age. At 2 weeks of age broiler and layer chicks (Davis et al., 1999) and turkey poults (Barber et al., 2004) spent most of their time under the brightest light available (200 lux). This preference for bright light may be due to the small increase in temperature in the brightly lit compartment. Preferences reversed in broilers and layers at 6 weeks of age, with birds spending most of their time under the dimmest light (6 lux; Davis et al., 1999). When allowed a choice of 1, 6, 20 and 200 lux light intensities, turkey poults preferred the brightest lights at 2 weeks of age, but at 6 weeks, chose either 20 or 200 lux (Barber et al., 2004). At 2 weeks of age in turkeys and broilers, all activities (resting, perching, feeding, locomotion, litter-directed activity and drinking) occurred primarily in bright light but at 6 weeks, resting and perching were seen most often in dim light and other behaviours in bright light (Davis et al., 1999; Barber et al., 2004). As the time spent performing active behaviours declines as birds age, the authors suggested that the older birds entered particular environments to perform specific activities. When they were inactive, the older birds may have preferred to be in the dimmest lit area where they were least aroused, and when they were active they entered the bright areas (Davis et al., 1999).

PHOTOPERIOD

Impact of the duration of light and its distribution on growth and feed conversion ratio: The use of constant or near constant light has traditionally been thought to maximise growth by allowing unlimited visual access to feed and water. However, much of the recent literature contradicts this claim. The length of the photoperiod interacts with age in relation to body weight gain. As birds age, they appear to be able to adjust many aspects, including their feeding behaviour, to compensate for longer dark periods. Growth of birds less than 3 weeks of age was reduced by short daylengths, but between 22 and 35 days of age, body weight was not affected by increasing daylength longer than 7 hours (Lewis et al., 2009). When measured at 32 and 39 days of age, weights were heaviest in broilers reared in 20 hour daylengths followed by 17 and 23 hour daylengths, with birds kept at 14 hour daylengths having the lightest weights (Schwean-Lardner et al., 2012b). At 49 days of age, birds with 17 and 20 hours of light were heavier than those at both 14 and 23 hours of light (Schwean-Lardner, 2012a). Similar impacts on growth rate (inclusion of darkness resulting in equal or heavier body weights than under near-continuous light) were found by Buyse et al. (1994) comparing near continuous lighting programs to increasing or decreasing programs, and Rozenboim et al. (1999) comparing body weight of broilers at 49 days under 23 hours of light to 16 hours of light. Broiler chickens with a 12 hour daylength had the best overall growth when body weight, feed conversion, age, liveability and genotype were accounted for, but breast yields at 54 days of age were greater for birds kept at a 21 or 24 hour daylength (Lewis et al., 2009). Performance decreased more rapidly for photoperiods less than 12 hours compared to longer than 12 hours. When comparing a split dark period to one dark period, larger weight gains were found in broilers reared on a lighting schedule of 8 hours light, 4 hours dark, 8 hours light, 4 hours dark than in broilers reared in 16 hours light, 8 hours dark (Duve et al., 2011).

Feed efficiency is also impacted by the amount of daylength birds are exposed to, but does not appear to be highly influenced by the distribution of the lighting regimen. With regards to daylength, adding darkness to a lighting program (ranging from 14 to 23 hours) results in improved feed efficiency (Schwean-Lardner et al., 2012b). This may partly be related to behavioural adjustments; as birds age they may anticipate the oncoming dark period and adjust their feed intake to consume similar amounts of feed as birds with longer light phases. Darkness itself also seems to improve feed efficiency, as birds kept under near-constant light were never the heaviest, regardless of age (Schwean-Lardner et al., 2012b). Feed conversion ratio did not differ between birds reared in 8 hours of darkness, split into 1 or 2 dark periods (Duve et al., 2011).

The lack of sleep can have negative consequences on bird welfare (Blokhuis, 1983), and in a variety of species has been shown to result in reductions in alertness and productivity (Boerema et al., 2003), increases in stress levels (Everson et al., 2008), reductions in neural activity (Fraser & Broom, 1990), and health (Speigel et al., 1999; Everson & Crowley, 2004; Copinschi, 2005). While it appears that birds can sleep during the light phase of the day, the quality of sleep is reduced (Ayala-Guerrero et al., 2003; Rattenborg et al., 2005). Long daylengths such as 23 hours of light have also been shown to eliminate the circadian rhythm of melatonin production, a neurotransmitter involved in the production of sleep, as well as remove the circadian pattern of many behavioural activities, resulting in the disruption of birds attempting to sleep (Schwean-Lardner et al., 2013b). This disruption, termed sleep fragmentation, can lead to all of the negative consequences found with complete sleep deprivation including reduced alertness and health issues (Bonnet, 2005). Sleep is also very important for young chicks, and lighting patterns can impact this sleep. Malleau et al. (2007) showed that chicks rested more when given a simulated brooding cycle (repeated periods of 40 minutes light and 40 minutes dark) than did those that were given long day cycles (19.33 hours light and 4.67 hours dark).

Research on lighting programs for use in commercial turkey production is not extensive, and the majority of work is well over 15 years old. Much of the older work was inconsistent in terms of results. Davis and Siopes (1985) found no differences in feed intake or growth rate when comparing 12, 23 or 24 hour lighting programs. Newberry (1992) found inconsistent results, with no differences in body weight of 17 week old birds in one experiment, and an increasing lighting program resulting in heavier turkeys than did constant light used in the second experiment.

Impact of the duration of light and its distribution on mortality: Mortality increased slightly with every extra hour of light above 12 hours (Lewis et al., 2009). Similar results were found by Schwean-Lardner et al. (2012a), where mortality increased with increasing daylength. Mortality rates in birds reared in 8 hours of darkness and two 4-hour dark periods separated by 8 hours of light did not differ between treatments (Duve et al., 2011). The incidence of sudden death syndrome decreased between 2 and 10 hours of daylength but increased as the photoperiod lengthened beyond 10 hours (Lewis et al., 2009).

Sherwin et al. (1999) found that injurious pecking, common in turkey production, was affected by photoperiod. An intermittent photoperiod was found to reduce the injuries due to feather pecking but they also found that this lighting program could result in blindness, which is an obvious welfare concern.

Impact of the duration of light and its distribution on leg abnormalities and foot pad dermatitis: Leg abnormalities were not affected by the daylength in broilers (Lewis et al., 2009). In contrast, Schwean-Lardner et al. (2013a) found both gait scores and foot pad lesions at 28 days of age increased linearly with daylength, indicating poorer foot health in broilers kept under longer daylengths. The proportion of foot pad dermatitis was higher in birds with two 4 hour dark periods compared to one 8 hour dark period (Duve et al., 2011).

In regard to skeletal health, Hester et al. (1983) found that a step-up program, as compared to a step-down program reduced leg abnormalities. Later work found that increasing photoperiods produced better leg structure than near constant or decreasing photoperiods (Classen et al., 1994). This is important, as leg abnormalities in turkeys can represent a major portion of flock mortality.

Impact of the duration of light and its distribution on behaviour: Long daylengths result in birds which are more lethargic and less active. This may contribute to the reduced amount of time spent at the feeder by birds kept in near constant light, despite having essentially unlimited access to feed. As daylength is increased from 14 to 23 hours an increasing amount of time is spent resting during the photophase with a similar amount of time spent resting in birds reared in 14 and 17 hours of light (Schwean-Lardner et al., 2012a). Birds reared at 23 hours of light, as compared to those exposed to either 14, 17 or 20 hours of light per day, were less reactive to the presence of an observer at both 30 and 47 days of age (Schwean-Lardner et al., 2012a). Tonic immobility, which is used as a measure of fearfulness, did not differ between treatments at 33 days of age, however (Schwean-Lardner et al., 2012a).

Comfort behaviours such as preening, stretching, dustbathing and litter pecking have been observed to vary with daylength. At 27 days of age, preening decreased linearly with increasing daylength (Schwean-Lardner et al., 2012a). A similar relationship was seen at 42 days of age, but preening peaked at 17 hours of light as opposed to 14 hours of light (Schwean-Lardner et al., 2012a). Preening was only observed in the scotoperiod in the 14 hour daylength birds at 42 days of age (Schwean-Lardner et al., 2012a). Dustbathing followed a similar pattern, decreasing with increasing daylengths at both 27 and 42 days of age (Schwean-Lardner et al., 2012a). Dustbathing was not observed in birds reared at 23 hours of light at 42 days of age. Stretching and litter pecking was observed less in 23 hour daylength birds compared to other groups (Schwean-Lardner et al., 2012a).

Standing, walking and running are affected by daylength. Increased daylength led to a decreased amount of time spent standing. Birds reared at 23 hours of light stood the least, while birds kept at 14 or 17 hours of light stood for a similar percentage of time (Schwean-Lardner et al., 2012a). The amount of standing during the dark period was low overall, but broilers kept at 14 hours of light stood the most during the dark period at 42 days of age, whereas 23 hour birds performed no activity during the dark period (Schwean-Lardner et al., 2012a). Walking followed a similar pattern; as daylength increased the amount of walking decreased, although similar amounts were seen in birds exposed to 14 and 17 hours of light (Schwean-Lardner et al., 2012a). Running was not seen in 23 hour daylength birds and occurred most in birds kept at 17 hour daylength (Schwean-Lardner et al., 2012a). Standing, running and walking likely contribute to bone health, thus long daylengths could be associated with weaker legs in broilers (Schwean-Lardner et al., 2012a). Decreased movement could also increase the level of breast blisters, hock burns or foot pad lesions (Deaton et al., 1978; cited by Schwean-Lardner et al., 2012a).

Birds prefer to eat and drink during the light phase, so it is generally thought that increasing the length of the dark period will decrease feed intake. This is not a linear relationship, as noted by Schwean-Larder et al. (2012b). Time spent at the feeder peaked in birds kept at 17 hours of light compared to those with longer (20 or 23 hours) and shorter (14 hours) daylengths at 27 and 42 days of age. Despite the preference to eat during the light phase, birds reared with short daylengths will learn to feed in the dark as early as 5 days of age (Lewis et al., 2009). Broilers reared in 14 hours of light, the shortest daylength tested, were the only observed group to feed during the scotoperiod, although the number of birds which performed this behaviour was small (Schwean-Lardner et al., 2012a). Broilers which were reared with 18 hours of daylength consumed very little feed during the dark period, while birds with less than 12 hour daylength had an increased feed consumption during the dark period (Lewis et al., 2009).

The length of darkness birds are exposed to impacts circadian rhythms, which as stated above, is important for resting and bird welfare. Use of continuous light does not allow birds to delevop circadian patterns in feeding behaviours (May & Lott, 1992; Ferrante et al., 2006).

Another technique which has generated interest is that of a split scotoperiod, also known as an intermittent lighting schedule, where two short periods of darkness are interspersed with periods of light throughout the day (i.e. 4 hours dark, 8 hours light, 4 hours dark, 8 hours light). Broilers reared with a split dark phase showed more feeding behaviour in the initial 20 minutes of the light phase, but overall feeding activity was higher in birds reared with 8 hours of continuous darkness and 16 hours light (Duve et al., 2011). Birds exposed to 8 hours of continuous darkness showed an increase in feeding behaviour 3 hours before the scotoperiod; this increase was not observed in birds with two 4 hour dark periods (Duve et al., 2011). This increase in feeding is thought to allow storage of feed in the crop as preparation for the dark period when feed was less accessible.

Preference of the duration of light and its distribution: Broilers have shown a preference to have darkness included in their lighting program. Work by Savory and Duncan (1982), with both broilers and layers, showed that birds would actively work for an inclusion of at least 4 hours of darkness per day.

LIGHT WAVELENGTH AND SOURCE

The interest in light colour, and its corresponding impact on welfare and productivity of birds, is increasing. Terminology used to describe wavelengths includes cool light, referring to lighting in the blue to green range; warm light, referring to lighting in the orange to red range and monochromatic, which is one light colour.

The impact of light wavelength and source on productivity: The impact of light source and colour has been tested in a number of research settings, often with inconsistent results. For example, Rozenboim et al. (1999) found that mini-fluorescent bulbs produced heavier male broilers than did fluorescent tubes or incandescent bulbs to 49 days, while Zimmerman (1988) found no difference in body weight gains in broilers raised on either incandescent of fluorescent bulbs. Kristensen et al. (2006) compared biolux lighting (type of fluorescent lamp which includes an ultraviolet component) to warm-white lighting, and found no effect on productivity parameters. In comparisons of white, blue and red light usage for meat bird production, no differences in productivity were found (JangHo & Ravindran, 2009). When red or white light were used during the dark period, again no impact was noted in productivity (Senaratna et al., 2009).

The use of green light for meat production has shown positive effects in productivity. Testing of 3 monochromatic colours (red, green and blue) produced heavier broilers under green light, and lowest under blue light (40 chicks per colour). Birds raised under green light had a better feed conversion ratio than those under blue (Arockiam et al., 2002). Other results have shown that the use of green light (Rozenboim et al., 2004; Cao et al., 2008) or green and blue light (Jing et al., 2007) as compared to red or white light improves productivity early in broiler life (0-27 days), but changing to blue light after this age improves productivity over the use of green light (Rozenboim et al., 2004; Jing et al., 2007; Cao et al., 2008). These increases in growth rate appear to be related to corresponding increases in testosterone production (Jing et al., 2007; Cao et al., 2008). This counteracts what has been seen in egg production birds, where red light advanced sexual development in some strains of hens (Gongruttananun, 2011). In turkey breeders, red light had no effect on productivity (Pyrzak et al., 1987). Meat yield of carcass, breast and thigh muscle of broilers was also higher under blue or green light as compared to red or white (Jing et al., 2007; Cao et al., 2008).

The impact of light wavelength and source on health: In one research study, mortality was higher under blue light than red or white light (Solangi et al., 2004). Use of red light early in life has been shown to reduce lameness in broilers (Prayitno et al., 1997). This is not consistent across literature, and in a comparison of biolux and warm light sources, source had no impact on lameness or hock burn (Kristensen et al., 2006). Injuries to the tails of turkeys were less common when the birds were reared under fluorescent light compared to incandescent light. Wing injuries also tended to be less common under fluorescent light (Moinard et al., 2001). In a similar study, no differences were found in injury levels of birds raised under fluorescent or incandescent (intermittent) lighting (Sherwin et al., 1999).

Light colour may impact the ability of birds to fight infections. Light appeared to affect splenocyte activity in an age related fashion, where green light increased activity early in life, and blue light did so later in broiler life (Xie et al., 2008a). T cell development follows the same patterns (Xie et al., 2008b). Mucosal development in the gut appears to be improved under green light at early ages and blue later in life, and altered lymphocyte numbers show improved immune functioning with these lighting programs as well. (Xie et al., 2011).

Melatonin production was enhanced under green LED lighting compared to blue, red or white (Jin et al., 2011).

The impact of light wavelength and source on behaviour: Reports on the impact of light colour on meat bird activity are inconsistent. Prayitno et al. (1997) found that broiler activity was higher under red (floor pecking, wing stretching and aggression) or white (walking) light than under blue or green light (5 minutes observation period for one day per week from 1 to 8 weeks of age). Japanese quail raised with or without supplemental ultraviolet light showed no difference in behaviour or corticosterone levels at 19 days of age (Smith et al., 2005). Comparison of white, blue and red light showed no significant difference in behaviour at 5 weeks of age (JangHo & Ravindran, 2009). Khosravinia (2007) tested broiler preference and activity under differing light colours at 1, 2 and 3 weeks of age (yellow, orange, green and red), and found a greater preference for, and more activity under, green light. In a program specifically designed to examine aggression, Solangi et al. (2004) found less agonistic behaviour with broilers under blue light than red or white when monitored at 2, 4 and 6 weeks of age.

Preference for light wavelength and source: Broilers can show preference for some light types over others. For example, Kristensen (2004) found a preference for biolux lighting (near-natural light in both colour and spectral composition) and warm-light (lumilux lighting with long wavelength component) over incandescent lighting. Prayitno et al. (1997) found that, given the choice, after an adjustment period, broilers generally preferred blue light over white, red or green. Only birds reared at a young age under blue light chose any other light colour later in life, and these birds chose green. In a comparison of broilers exposed to either warm (4100K) or cold (6065K) LED lighting, birds preferred to spend time in the cold LED light rooms (Riber, 2013).

IN OVO LIGHTING

In the incubator, light in itself and its source has been shown to impact bird performance. Providing light to eggs in ovo resulted in more feeding activity by broilers in the 2 hours after the lights came on than broilers incubated in darkness (Archer et al., 2009) and better physical symmetry, suggesting lower developmental stress. No negative effects were seen in productivity. The increase in feeding frequency was also noted by Dayioğlu and Özkan (2013), along with higher post-hatch early growth in broilers with fluorescent lights were used during incubation as opposed to dark incubation. Rozenboim et al. (2003) showed that body weights of female turkeys and breast meat yield between 28 and 59 days of age were heavier when eggs were pulsated with green lighting in ovo as compared to dark incubation. This could be a result of proliferation of adult muscle cells (Halevy et al., 2006). MiaoEn and HowHong (2008) tested LED lights of either blue, green, red, amber or warm white light, and found that while photostimulation sped up embryo development, greater abnormalities occurred in hatching turkey poults with the use of green light.

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8. METHODS OF EUTHANASIA

CONCLUSIONS

1. **Very little research has been done on the humaneness of various methods of euthanasia.**
2. **Properly performed blunt force trauma, non-penetrating captive bolt and penetrating captive bolt result in immediate unconsciousness leading to death.**
3. **Manual cervical dislocation is more effective than mechanical cervical dislocation; however, neither method may result in instantaneous loss of consciousness.**
4. **Electrical stunning and stunning/killing are complex methods of euthanasia and in order to ensure an immediate loss of consciousness, proper equipment and procedures are required.**
5. **Carbon dioxide is aversive. The exact concentration and time period required to induce unconsciousness and death are not precisely known, but concentrations higher than 20% for a minimum of 5 minutes effectively cause death. Introduction of 100% carbon dioxide to gradually increase the level in breathing air can minimise the respiratory discomfort.**
6. **Whole-house gassing using carbon dioxide is an effective method of mass depopulation but respiratory distress likely occurs before loss of consciousness.**
7. **Water-based foam may cause significant distress, and therefore more research is required if this method is to be used. Foam containing inert gases reduces the time to loss of consciousness but also requires further research.**
8. **Masceration (mechanical destruction), when performed carefully with specially designed equipment, results in instantaneous death in day old chicks and adult birds. When the technique is used for killing of adult birds, the number of birds entering the equipment at one time can influence the effectiveness of the equipment.**

INTRODUCTION

The term euthanasia means "good death", quantified by minimal pain and distress (American Veterinary Medicine Association [AVMA], 2007). Techniques used to euthanize an animal result in a rapid loss of consciousness followed by cardiac or respiratory arrest and the ultimate loss of brain function (AVMA, 2007). Pain can only be felt in a conscious animal; the method of choice is less critical if the animal is first rendered unconscious, providing the animal does not regain consciousness prior to death (AVMA, 2007). Assessing animal welfare during euthanasia is focused on affective states and minimising negative states such as pain and distress. The biological function and natural behaviour of the animal are irrelevant at this time.

Some methods of euthanasia require that the animal be handled, and proper handling is vital to minimise the pain and distress in the animals (AVMA, 2007). Selecting the most appropriate method for the situation depends on the species of animal, availability of restraint, skills of the personnel, and the number and size of the animal (AVMA, 2007). The AVMA (2007) used the following criteria to assess the welfare implications of methods of euthanasia and their practicality:

1. ability to induce loss of consciousness and death without causing pain, distress, anxiety, or apprehension
2. time required to induce loss of consciousness
3. reliability
4. safety of personnel
5. irreversibility
6. compatibility with requirement and purpose
7. emotional effect on observers or operators

8. compatibility with subsequent evaluation, examination, or use of tissue
9. drug availability and human abuse potential
10. compatibility with species, age, and health status
11. ability to maintain equipment in proper working order, and
12. safety for predators/scavengers should the carcass be consumed.

GENERAL MODES OF EUTHANASIA

Death through euthanasia is caused by one of three basic mechanisms: hypoxia, direct depression of the neurons necessary for life function or physical disruption of the brain activity and destruction of the neurons necessary for life (AVMA, 2007). As the intention of euthanasia is to provide a good death, an ideal method of euthanasia will induce immediate (less than 1 second) and unequivocal loss of consciousness; or when the loss of consciousness is not immediate, unconsciousness should be induced in a non-aversive way and should not cause anxiety, pain, distress or suffering in conscious animals (European Food Safety Authority [EFSA], 2004).

ASSESSING SENSIBILITY

Assessing loss of consciousness, or insensibility, and brain death after euthanasia can be done using an electroencephalogram (EEG), evoked responses, brain stem and spinal reflexes and behavioural measures such as vocalization, rhythmic breathing, and jaw and muscle tone. The EEG is considered the most reliable indicator because it records a measure necessary for consciousness: activity in the cerebral cortex (Erasmus et al., 2010a). Insensibility can be recognized by the distortion or disappearance of normal patterns in the EEG, or by an increase in abnormal patterns or the disappearance of all signals. Evoked responses are a result of electrical activity in the cortex and the absence of brain activity (measured with an EEG) in response to a stimulus indicates the bird is unable to receive and process external stimuli.

While the EEG and evoked responses are considered to be the most reliable indicators, their impracticality outside of a laboratory leads to the common use of other measures such as brain stem and spinal reflexes (Erasmus et al., 2010a). Insensibility is indicated by the total loss of both voluntary actions and involuntary reflex reactions in response to painful stimuli. As the perception of pain is lost at the onset of insensibility, the absence of a pain reflex is one of the most practical means of assessing insensibility in the field (Erasmus et al., 2010a). Complete insensibility can also be detected using the absence of brain stem reflexes which include the pupillary light reflex, the corneal reflex, or the nictitating membrane reflex (movement of the nictitating membrane across the eye) (Erasmus et al., 2010a).

Tonic seizure is also used to indicate insensibility, particularly with electrical stunning. Tonic seizure is characterised by stiffening and arching of the neck, rigid extension of the legs, wings folded tightly around the breast and constant body movements (EFSA, 2004). As well, the birds' eyes will be wide open and will not blink when touched and rhythmic breathing will be absent. The return of rhythmic breathing and eye reflexes indicates a return to consciousness.

PHYSICAL METHODS OF EUTHANASIA

When properly used, physical methods of euthanasia may result in less fear and distress in the animal and can be more rapid, painless, humane, and practical than other forms (AVMA, 2007). In certain situations, physical methods of euthanasia are the most appropriate; however, these methods can be aesthetically displeasing and since most methods involve trauma, there is a risk for animals and humans (AVMA, 2007). Physical methods which are considered acceptable for euthanasia of birds are gunshot, blunt force trauma, non-penetrating captive bolt, cervical dislocation, decapitation, and in some cases maceration.

<u>Blunt force trauma:</u> Blunt trauma using a metal pipe or bat was found to consistently cause immediate insensibility leading to death in turkey toms, hens and turkey broilers (Erasmus et al., 2010b). The effectiveness

was more variable with turkey broilers than with turkey toms, with more turkey broilers needing a second application, possibly due to the smaller target (Erasmus et al., 2010b).

Penetrating and non-penetrating captive bolt: The use of a penetrating captive bolt has been found to cause immediate cessation of breathing, loss of neck muscle tension and eye reflexes in broilers when properly operated (Raj & O'Callaghan, 2001). These results were found only when a 6mm bolt was placed perpendicular to the skull and delivered with air line pressure of 827 kPa. A smaller bolt (3mm) and/or a lower air line pressure (620 kPa) did not cause unconsciousness and placing the captive bolt at angles greater than 90° to the skull (leaning towards the beak) stunned only 4 of 9 broilers (Raj & O'Callaghan, 2001).

The use of pneumatically operated non-penetrating captive bolt has been investigated as a method for humane euthanasia of poultry on-farm (Erasmus et al., 2010b). When applied perpendicular to the skull directly above the cerebral cortex, immediate insensibility was induced reliably. A non-penetrating captive bolt allows a consistent force to be applied to the skull, independent of the operator's strength.

A non-penetrating captive bolt (8mm diameter and airline pressure of 758-827 kPa) appears similar to blunt force trauma in the end time of convulsion and proportion of birds that regain consciousness, but may be more consistent in small turkeys (Erasmus et al., 2010b). Microscopic hemorrhage was observed in the brains of all turkeys euthanized with non-penetrating bolt gun with a diameter of 8mm and airline pressure of 724-827 kPa, as well as with blunt force trauma (Erasmus et al., 2010c). Skull fracture was more severe when a non-penetrating captive bolt was used than when blunt force trauma when applied to toms and turkey broilers (Erasmus et al., 2010c).

The application of captive bolts causes violent involuntary wing flapping and clonic convulsions which can be a concern for operator safety.

Cervical dislocation: Although it has rarely been investigated scientifically, cervical dislocation is a recognized method of euthanasia by the AVMA (2007) and the World Organization for Animal Health [OIE] (2010). The OIE (2010) recommends that cervical dislocation be used on conscious birds only if they weigh less than 3kg and when the number of birds to be killed is small and other methods of euthanasia are not available. There are two ways cervical dislocation is performed: manually and mechanically. The manual method of cervical dislocation is done by grasping the bird at the base of the skull and rapidly stretching the neck to separate the spine and spinal column from the base of the brain. Mechanical cervical dislocation involves the use of an instrument such as vise grips or burdizzo which is applied to the neck to crush and separate the vertebral column.

Erasmus et al. (2010b) found that turkey broilers euthanized with manual cervical dislocation showed signs of sensibility (gasping and reflexes) for 43 seconds on average after the procedure. Gregory and Wotton (1990) also found that less than 10% of birds undergoing cervical dislocation showed signs of concussion and that 25% of birds subjected to manual cervical dislocation did not show immediate changes in visual evoked responses (VER), averaging 105 seconds before loss of VERs. Similarly, Erasmus et al. (2010b) also noted eye reflexes present in all turkey broilers euthanized with manual cervical dislocation. Although signs of sensibility occurred for some time after application of the procedure, cervical dislocation consistently resulted in the death of the bird in about 140 seconds, and no additional procedure was needed (Erasmus et al., 2010a). Dawson et al. (2007) reported that cessation of clonic convulsions and time of cardiac relaxation as measured by electrocardiograph (ECG) occurred on average in 128 and 154 seconds, respectively, following cervical dislocation in broilers.

Mechanical cervical dislocation by neck crushing causes blood vessel to rupture and blood to flow under the scalp (Erasmus et al., 2010c). Hemorrhage occurs at the site of cervical dislocation, leading to reduced blood flow and oxygen supply to the brain (Erasmus et al., 2010c). Death likely results from cerebral hypoxia and ischemia and does not appear to be instantaneous. Turkey hens killed with a burdizzo all had visible nictitating membrane reflexes for an average of 106 seconds following the procedure (Erasmus et al., 2010b). Likewise, visual evoked responses were retained for 192 and 245 seconds, respectively, when ventral and dorsal approaches to crushing with a mechanical device were used on broiler chickens (Gregory & Wotton, 1990).

Decapitation: Decapitation is severance of the neck near the head. This method has received little attention in the scientific literature, but one report on anesthetised birds found that decapitation did not immediately cause unresponsiveness in the chicken's visual cortical pathway to a visual stimulus (Gregory & Wotton, 1986). The normal waveform response persisted for approximately 30 seconds following decapitation. This method was significantly more rapid in the loss of spontaneous EEG activity than methods where 1 or both carotid and/or jugular veins were cut (Gregory & Wotton, 1986). It is not known whether these lasting responses are associated with any cognitive processes in the brain or what is the duration to insensibility using this method. A major concern with the application of decapitation is the potential for contamination due to the spillage of blood (EFSA, 2004).

Maceration: Maceration is labelled as an acceptable method of euthanasia for day-old chicks and eggs by the OIE (2010). The use of a specifically designed machine with rotating blades or projections causes immediate fragmentation and death of day-old poultry and embryonated eggs (AVMA, 2007). Care should be taken when introducing birds to prevent equipment jamming, birds rebounding from blades or birds suffocating before they are macerated (OIE, 2010). There are no scientific reports available on maceration to consider.

Maceration is also occasionally used for disposal of end-of-cycle laying hens and may provide another option for mass slaughter on farm. An evaluation of the procedure (performed on dead and live birds) found that the average time for individual dead birds to pass through the macerator was 1.53 seconds (Rouvinen-Watt et al., 2004). Individual live birds passed through in slightly less time, at an average of 1.28 seconds. Nearly 70% of live birds entered the macerator head first when a single animal was introduced at one time, but this dropped to 43% when two birds were introduced simultaneously and if three birds were introduced at least one bird did not enter head first (Rouvinen-Watt et al., 2004). When one live hen was introduced, about 35% vocalised, however, over 20% of dead birds vocalised, likely due to compression of the vocal cords as the bird passed through the machine (Rouvinen-Watt et al., 2004). Vocalisation increased considerably to about 60% when two live birds were introduced and at least one of three live birds vocalised if three were introduced.

ELECTRICAL STUNNING AND STUN/KILL METHODS

Head only electrical stunning uses the application of an electric current across the head of the bird. Birds are normally inverted and restrained in a cone or shackles. The effectiveness of electrical stunning is affected by the surface area of the electrode which is in contact with the head, the electrical properties of the electrode material, the peak or peak-to-peak voltage available to the stunner, the amount of frequency of the current and the pressure applied during stunning (EFSA, 2004). Electric stunners have variable properties such as voltage, current, waveform and frequency and are therefore difficult to compare and standardise. Furthermore, the depth and duration of unconsciousness induced using the variety of waveform and frequency combinations has not been determined, nor has the cumulative effects of electrical stunning and the cutting of blood vessels at slaughter (EFSA, 2004).

The European Food Safety Authority (2004) recommended that when using a constant voltage stunner (110V root mean square [RMS]) supplied with 50Hz AC, restrained birds be exposed to a minimum RMS or average current of 240mA for chickens and 400mA for turkeys for a minimum of 7 seconds. In addition, neck cutting should be performed within 15 seconds from the end of the stun.

If stunning is done with a variable voltage/constant current stunner that delivers sine wave AC and uses low impedance electrodes, the minimum RMS current recommended is 100mA for a 50Hz frequency, 150mA for a 400Hz frequency, and 200mA for a 1500Hz frequency (EFSA, 2004). In these cases, the current should be applied for at least 1 second and both the carotid arteries should be cut within 20 seconds of the end of the stunning.

A successful stun can be signified by the immediate onset of clonic-tonic seizure, a distinct period of tonic seizure, apnoea during tonic seizure, and/or a lack of wing flapping during bleeding (EFSA, 2004).

Water bath electrical stunning and water bath stun/killing are common methods used for commercial slaughter of birds, but are not practical for on-farm use.

Electrical stun/killing using dry electrodes is a method which is not currently used under commercial condition, but is being developed for chickens and may be practical for on farm use. Generally, head-only electrical application is used to induce unconsciousness and followed immediately by head-to-vent application by previously positioned electrodes. Because head-only stunning results in wing-flapping, this method should only be performed on restrained poultry (Raj et al., 2001). If a constant voltage stunner is used, a minimum RMS current of 240mA of 50Hz AC applied for at least 5 seconds across the head to stun and another 5 seconds across the body is needed to kill chickens without interruption (EFSA, 2004). If a variable voltage/constant current stunner is used, a minimum RMS current of 150Ma of 50Hz AC applied for 1 second across the head and 1 second across the body is needed (EFSA, 2004).

GASSES

Gassing is considered to be an acceptable method for euthanizing poultry (AVMA, 2007; EFSA, 2004; OIE, 2010). Gassing limits the availability of oxygen in the lungs and brain (hypoxia) or directly affects the central nervous system. The most commonly used gasses for stunning poultry are carbon dioxide (CO_2), argon (Ar) and nitrogen (N_2) (Alphin et al., 2010). Carbon dioxide directly affects the central nervous system (through hypercapnia) as well as displacing oxygen in the air causing hypoxia, while N_2 and Ar displace oxygen only. Because gasses and gas mixtures do not immediately cause unconsciousness, they should be given in such a way to balance the loss of consciousness with the displacement of oxygen (Alphin et al., 2010). If gasses kill birds relatively quickly, they may be considered acceptable despite their aversiveness, especially when used to prevent the spread of disease.

Carbon dioxide and gas mixtures: Carbon dioxide has an anesthetic effect, a desirable characteristic for a method of euthanasia. However, it is an acidic gas and is an aversive substance to many animals and birds, as well as a potent respiratory stimulant (Raj, 1996; Sandilands et al., 2011). Turkeys exposed to 72% CO_2 gasped, vocalised and shook their heads and more than half of the birds avoided or attempted to avoid the gas (Raj, 1996). The replacement of atmospheric air with CO_2 was also accompanied by gasping and head shaking at about 47 seconds and 38 seconds after gas induction, respectively, by broiler chickens (Gerritzen et al., 2004). Respiratory disruption was observed in broilers by McKeegan et al. (2006) when CO_2 was delivered in air or in N_2, with the greatest number of birds showing respiratory disruption at 25% CO_2. Even at low levels (10%) of CO_2 in air, headshaking and respiratory disruption were observed and birds were less willing to continue feeding in the presence of CO_2 as the concentration increased (McKeegan et al., 2006). The similar responses seen with both carrier gasses suggest that the response of the birds are due to CO_2 itself (McKeegan et al., 2006).

Argon is less aversive than CO_2; more turkeys were willing to enter a feeding chamber filled with Ar or Ar and CO_2 than with CO_2 and air (Raj, 1996). No signs of respiratory distress were observed in turkeys exposed to lethal concentrations of Ar (Raj, 1996). Broiler chickens showed less aversion to gas mixtures of high concentrations (90%) of N_2 or Ar with low concentrations of CO_2 than to CO_2 in air, but it appears that all gas mixtures were somewhat aversive (Sandilands et al., 2011).

The use of 100% CO_2 to gradually increase the CO_2 in the breathing air has been recommended to prevent possible discomfort in the birds (Gerritzen et al., 2004). In order to kill all birds, it's been suggested that a level of at least 40% CO_2 maintained in the breathing air for 30 minutes is necessary (Gerritzen et al., 2004), but Turner et al. (2012) found exposure to increasing CO_2 concentrations greater than 20% for at least 5 minutes ensured irreversible brain death in laying hens. After the initial response of exposure to CO_2, broilers showed a loss of posture on average 172 seconds after induction of 100% CO_2 at 6 weeks of age and occurrence of convulsions from 177 seconds to 700 seconds. Laying hens showed a loss of posture by approximately 120 seconds after the onset of CO_2 entry, a response which was thought to correlate to unconsciousness (Turner et al., 2012). There is some evidence that a total loss of posture is associated with the loss of sensibility, but in some cases convulsions occur before the onset of insensibility (Gerritzen et al., 2004). Brain death, detected by a flat line on an EEG, occurred at approximately 5 minutes after the gas was turned on, whereas heart rate showed abnormalities in the first 2 minutes but acute myocardial infarction and hypoxia was not noted until nearly 7 minutes (Turner et al., 2012) A flat line ECG was noted by all chickens by 11 minutes after the onset of gas induction (Turner et al., 2012).

Through adaptation to diving, it has been suggested that waterfowl may be less susceptible to hypoxia and hypercapnia. However, Gerritzen et al. (2006) found that White Pekin ducks and turkeys died within 13 minutes with CO_2 concentrations increasing from 0 to 44% with similar reaction patterns seen with both species. Loss of posture was observed at 22.7% CO_2 for ducks and 19.2% for turkeys (Gerritzen et al., 2006). The behavioural responses of the ducks to this method of euthanasia were not observed under these conditions (Gerritzen et al., 2006).

MASS EUTHANASIA

In some cases, poultry are required to be killed on farm in an emergency such as a disease outbreak or natural disaster. Euthanizing birds on farm minimises the risk of disease transfer to other poultry and, in some cases, humans. In these circumstances biosecurity and risks to humans involved in the procedure are also important considerations. Depopulation of birds such as end-of-lay hens is another potential application for mass on-farm euthanasia. These birds are often transported significant distances to slaughter plants and on-farm euthanasia would eliminate the transportation stress on these animals (Turner et al., 2012).

The introduction of gaseous agents into the houses is one method which is appealing because it can be applied to commercial flocks with minimal handling and good biosecurity (McKeegan et al., 2011). Alternatively, birds can be carried out of the barn and placed in containers containing lethal concentration of gasses, or birds can be placed in containers and gasses introduced, but methods that require individual birds to be caught are labour intensive (Raj et al., 2006).

Whole-house gassing: In whole-house gassing, the poultry house is sealed to prevent gas leakage and the gas is introduced into the building. Carbon dioxide is one of the most widely used gases for large scale emergency depopulations (Alphin et al., 2010). Partial-house gassing is also done, and follows a similar procedure to that of whole-house gassing. If CO_2 is used, high pressure liquid CO_2 is injected into the building until the gas concentration in the air reaches a suitable concentration (40% or greater) to euthanize birds throughout the house (Alphin et al., 2010).

One of the biggest challenges related to whole-house gassing under commercial conditions is achieving the required gas concentration rapidly and consistently. Gas delivery was not uniform throughout the building and interestingly, areas nearest the gas inlet took longer to reach a target concentration of 45% CO_2 than distant and central locations (McKeegan et al., 2011).

It is also very difficult to accurately determine the time to loss of sensibility in birds during whole house gassing. Postural changes, decreased brain activity and cardiac arrest were used by Turner et al. (2012) on samples of instrumented birds within a 24,000 bird caged layer house and a 13,100 free-run layer house to estimate loss of sensibility. They found unconsciousness occurred at concentrations of 18 to 20% CO_2 and less than 20% O_2 concentrations. Prolonged exposure of at least 5 minutes to CO_2 concentrations exceeding 20% was needed to ensure irreversible brain death (Turner et al., 2012). In another report, respiratory and EEG traces on 8 birds spaced throughout a layer house indicated that unconsciousness occurred at nearly 8 minutes on average, and the average time to death after the onset of CO_2 delivery was approximately 16 minutes, ranging from 13.7 to 22.1

minutes (McKeegan et al., 2011). It is not clear why these differences occurred, but it may be related to the speed of gas delivery related to the number of birds in the barn.

Although time to loss of consciousness was measured from the onset of gas delivery, a response was not seen immediately because birds do not experience the gas immediately on delivery. The period of the birds' awareness of exposure to gas was calculated as lasting between 4 and 8 minutes after the onset of gas delivery (McKeegan et al., 2011). This period corresponded with the most severe cardiac and respiratory responses of the birds. Initially, bradyarrythmia occurred in birds, during a period when consciousness was a strong possibility (McKeegan et al., 2011). Respiratory responses were also evident, with prolonged inspiration, increased tidal volume and decreased breathing frequency occurring in all observed birds (McKeegan et al., 2011). This is thought to be a response to an unpleasant experience (McKeegan et al., 2011).

Another concern with using liquid CO_2 is the potential for severe hypothermia, as the liquid CO_2 is injected into the building at -78^{o}C (McKeegan et al., 2011). Temperatures below 0^{o}C were recorded in a layer house when CO_2 was introduced and body temperatures fell to mild to moderate but not lethal hypothermic levels (McKeegan et al., 2011). Similarly, Turner et al. (2012) found that barn temperatures decreased to reach -23°C at 13.5 minutes after gas was delivered in one experiment, but in another the lowest recorded temperature was only 15°C. In these experiments, body temperatures did remain near normal while the birds were alive, and there were no signs of ante mortem hen freezing (Turner et al., 2012).

Based on detailed observations, Turner et al. (2012) concluded that CO_2 delivery to whole barns is a viable method for depopulation, but some welfare concerns include signs of respiratory irritation and muscle acidosis before consciousness is lost. McKeegan et al. (2011) also concluded that whole-house gassing is highly effective for depopulation of layer hen barns, but again respiratory responses may indicate reduced welfare.

<u>Fire fighting (water-based) foam:</u> Foam-based methods for killing birds in floor barns use medium or high expansion foam generation equipment to spread a blanket of water-based fire-fighting foam over the top of the birds. Immersion in the foam causes rapid occlusion of the airway and results in death within a few minutes (Alphin et al., 2010). Water-based foam has been approved by the United States Department of Agriculture (USDA) as a method for mass depopulation of poultry floor barns. One of the main advantages of this method is that the house does not have to be sealed, something that is especially appealing for open-sided barns. However, because this method involves the physical separation of the upper airway from atmospheric air, it has been compared to death by drowning, suffocation or asphyxiation (Raj et al., 2008) which are not considered to be humane methods of killing.

Euthanasia using water-based foam has also been tested on Pekin and call ducks, which take longer to show cessation of movement than broilers (Benson et al., 2009). ECG measurements indicate that ducks take longer to show cardiac arrest after induction (Benson et al., 2009). No measures of loss of consciousness were done in this study, so the welfare implications of using water-based foam for waterfowl require more investigation if this method is to be utilised.

<u>Foam with inert gasses:</u> One concern with the use of water-based foam for euthanasia is that the cause of death may be drowning or suffocation. The use of inert gasses within the foam has been investigated recently as a means to improve the time to unconsciousness and make the procedure more humane. The foam would serve as a carrier for the gas and as the bubbles of foam were disrupted or burst, they would release the infused gas, leading to unconsciousness and death of the bird (Alphin et al., 2010). Results have shown that foam with CO_2 gas has a shorter average time to EEG silence than CO_2 alone, indicating that the birds are killed by the foam and not by the release of the CO_2 (Alphin et al., 2010). Foam with CO_2 gas had similar times to EEG silence (120 seconds) as CO_2 gas (134 seconds) and foam with ambient air (134 seconds), all of which were faster than Ar with CO_2 gas (195 seconds) but these differences were not statistically significant (Alphin et al., 2010). Time to loss of consciousness, which is likely to occur prior to EEG silence, has not been determined for these methods.

Foam containing pure nitrogen has also been investigated briefly (Raj et al., 2008). Dry foam containing pure nitrogen was hypothesised to either release gas or deplete atmospheric oxygen upon contact with the birds, leading to acute hypoxia. A small-scale experiment confirmed this hypothesis with birds exposed to dry foam with nitrogen dying within seconds.

UNHATCHED EGGS

Mellor and Diesch (2007) reviewed older literature on the anatomical, electrophysiological and behavioural evidence for development of awareness in chicks within the context of more recent understanding of fetal neurophysiology. They define awareness to be "when a perceived stimulus involves the cerebral cortex (or equivalent avian brain structures) and causes responses that the individual may or may not be aware of". During incubation, the neural anatomy is functionally immature and electrical activity does not appear until day 13 or 14. From that time until pipping, EEG patterns are suggestive of continuous state of sleep-like unconsciousness, although pre-hatching vocal-auditory interactions suggest that the chick may have some level of awareness during the final stages of incubation. EEG data indicate the first 30 minutes following hatching are characterized by a sleep-like unconsciousness; EEG patterns characteristic of arousal appear when the chick hold its head upright and rights itself within the 2 hours after hatch. The EEG traces develop into patterns typical of those of the alert chick at around 6 hours. The authors suggest that research is needed using more advanced technology to clarify discrepancies between EEG and behavioural data during late incubation and hatch.

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9. SURGICAL INTERVENTIONS IN TURKEYS

This section reviews the literature related to surgical interventions in turkeys only. Because research in this area focuses on laying chickens, more information can be found in the *Code of Practice for the Care and Handling of Poultry (Layers): Review of Scientific Research on Priority Welfare Issues.*

CONCLUSIONS

1. **There has been very little research using modern methods of surgical interventions in turkeys.**
2. **Consistent performance (weight gain, feed efficiency, mortality, etc.) results have not been reported with regard to beak trimming in turkeys. Genetic strain, method of trimming and sex of the birds have led to differing results.**
3. **Agonistic behaviours and feather pulling are also not consistently impacted by beak trimming and incidence varies with age. Beak trimmed birds may spend more time pecking and pulling feathers than their untrimmed counterparts due to a reduced ability to grasp and pull feathers.**
4. **Beak trimming with an electric current appears to cause the most damage to the beak and the slowest healing time. Secateurs showed little damage to the beak and a heated blade caused variable amounts of damage. Little information is available describing the impact of infrared treatment of beaks, although evidence in laying hens indicates that little or no pain occurs with this treatment.**
5. **Toe trimming does not consistently impact performance traits, but may lead to increased mortality. Carcass grades are generally higher in groups of turkeys with trimmed toes.**
6. **Toe trimming may provide an entry site for bacteria, especially if wounds are improperly cauterised, which can lead to increased disease and mortality.**

INTRODUCTION

Measures for evaluating the welfare of turkeys in regard to surgical interventions can include the biological function of the animals (health and productivity) and their affective state (subjective experiences). In terms of natural living, any surgical intervention that alters the natural morphology of the bird would raise ethical concerns for those holding this viewpoint. Research to date has largely focused on:

1. In terms of biological functioning, studies have looked at some production parameters, such as the growth, feed efficiency, carcass damage and mortality.
2. In terms of affective states, the behavioural changes, particularly in aggressive behaviour have been investigated to some degree.

In the current scientific literature (the majority of which was conducted more than twenty years ago), there has been little investigation into surgical interventions performed on turkeys. Many of the available reports are dated and may not always reflect current genetics or production practices. There is a distinct lack of research on the potential for these procedures to cause immediate or long term pain, and much remains to learn about these practices.

BEAK TREATMENTS

Beak trimming is a practice which is used to reduce cannibalism and feather pecking. The reduction in these behaviours is likely to improve the overall welfare of the birds, but the procedure itself may be painful. Beak trimming may be necessary while other alternative measures to reduce feather pecking and cannibalism are investigated. More information on feather pecking and cannibalism can be found in the respective section in this report.

There are many different methods used to trim beaks, but the aim with all treatments is to remove the end of the beak or the end of the top half of the beak. Common commercial techniques include hot blade trimming, infrared treatment or microwave treatment. Hot blade trimming is performed when the tip of the beak is pressed onto a hot plate, resulting in burning and cauterization of beak tissue. This may still be done at commercial hatcheries or on-farm. In the latter procedures, high intensity microwave or infrared energy is applied to the tip of the beak at the hatchery. The result is that the exposed tissue dies over a period of time. Less commonly used methods of beak treatment include a high voltage electric current used to burn a hole through the beak, the tip of which falls off 3 to 7 days later. Arc beak trimming has also been practiced.

Performance characteristics: Research to date has been inconclusive regarding the impact of beak trimming or treatment on productivity. For example, turkeys beak trimmed at one day of age using a high voltage electric current had similar growth as those not beak trimmed during the first 3 weeks of age, but by 6 weeks of age beak trimmed males were heavier than untrimmed males and this trend continued throughout the study (Cunningham et al., 1992). Noble et al. (1994) also found that male turkeys of two different genetic strains beak trimmed with an arc trimmer (also termed a "Bio-Beaker, this equipment uses an electrical current and produces a small hole through the beak; the tissue anterior to the hole becomes necrotic and falls off (Renner et al., 1989) had higher body weights than those with intact beaks at 8, 12, and 16 weeks of age, but not at 4 or 18 weeks. In contrast, Noble and Nestor (1997 found no difference in weight gain in turkeys beak trimmed with a hot blade as compared to untrimmed birds, but body weights were only measured to 8 weeks of age. Denbow et al. (1984) found no difference in weight of male turkeys at any age whether beak trimmed using a high voltage electric current or were left untrimmed to 20 weeks of age.

Females trimmed using a high voltage electric current did not differ in weight from untrimmed birds until 12 weeks of age (Cunningham et al., 1992) or until 16 weeks of age (Leighton et al., 1985). At this point in each study, trimmed birds weighed less than untrimmed birds. Noble and Nestor (1997) found no difference in weight gains of female turkeys; however this study ended at 8 weeks of age.

Method of trimming has been found to influence the productivity of turkeys, depending on the genetic strain. Females in three of six strains tested, arc trimmed at hatch, had lower body weights at 8 weeks than those that had the top half of their beak removed using a hot blade at 13 days of age (Noble et al., 1996a). In two of these strains, female turkeys which had both half of the top beak and slightly less of the lower beak trimmed at 13 days had higher 8 week weights than arc trimmed turkeys, but lower than those with the top beak trimmed only. No difference in body weight due to type of trimming was found at 16 or 20 weeks of age (Noble et al., 1996a). Male turkeys in one of six strains tested that had their beaks trimmed using the arc method had lower body weights at 8 weeks than those with the top half of their beak trimmed at 13 days of age with a hot blade. In turn, turkeys from this strain with the top half of their beak trimmed had lower weights than those with both half of the top beak and slightly less of the bottom beak trimmed at 13 days of age (Noble et al., 1996a). The same pattern was found for a different strain of male turkeys at 16 weeks of age, but body weight was equal at 20 weeks of age (Noble et al., 1996a).

Results relating to feed intake varied between studies and sexes. Females trimmed using a high voltage electric current ate less than untrimmed females, whereas trimmed males consumed more than untrimmed males from 13-18 weeks of age (Cunningham et al., 1992). In contrast, males with arc-trimmed beaks had lower feed intake at 4-8, 12-16 and 0-18 weeks of age (Noble et al., 1994). Finally, no difference in feed intake or feed efficiency was found in beak trimmed or untrimmed males (Denbow et al., 1984). Similarly, no impact on feed consumption or feed conversion was found in either sex (Noble & Nestor, 1997). However; feed wastage was reduced by beak trimming in two large bodied turkey strains but not in one medium bodied strain (Noble & Nestor, 1997). Feed to gain ratio was better in arc beak trimmed toms than untrimmed toms throughout the growing period (Noble et al., 1994).

Feather cover is important as a protective layer against scratches, as well as insulative against cold temperatures. Feather scores were better at 12 weeks in trimmed male turkeys, but at 20 weeks this effect was no longer evident (Denbow et al., 1984). Feathering was also poorer in female untrimmed turkeys at 16 weeks of age than those that were trimmed with an electric current (Leighton et al., 1985).

Mortality was greater from 12 to 20 weeks of age in groups of male turkeys that were not beak trimmed as compared to those that were (Denbow et al., 1984), but did not differ from 0 to 16 weeks of age between treatment in groups of female turkeys (Leighton et al., 1985), male turkeys of two strains from 0 to 18 weeks of age (Noble et al., 1994) or six strains from 0 to 20 weeks of age (Noble et al., 1996a).

<u>Behaviour and beak related injuries:</u> The impact of beak trimming on beak inflicted injuries may vary with strain. One strain of male turkeys with intact beaks had three times as many injuries over the growing period (0 to 18 weeks) as those with trimmed beaks, while another strain showed no difference between trimmed or not trimmed in the number of beak inflicted injuries (Noble et al., 1994).

Overall, no difference was found in agonistic behaviours performed by females to 18 weeks of age; whereas untrimmed males committed more agonistic behaviours than trimmed males (Cunningham et al., 1992). Three week old untrimmed females committed more agonistic behaviours than their trimmed counterparts while at 6 weeks of age, more agonistic acts were performed by trimmed females than untrimmed females (Cunningham et al., 1992). Denbow et al. (1984) found no treatment effect of beak trimming on agonistic behaviour, or on non-agonistic feather pecks and pulls except at 12 and 20 weeks of age, when trimmed male turkeys had a greater number of non-agonistic feather pecks than untrimmed birds. Results found by Leighton et al. (1985) indicated that at 12 and 16 weeks of age, beak trimmed female turkeys pecked each other significantly more than untrimmed females. There was no detectable difference between groups in pecking behaviour at 8 weeks of age (Leighton et al., 1985), which may suggest that this behaviour develops with time in beak trimmed birds. Beak trimmed birds also have a reduced ability to grasp and pull feather compared to untrimmed birds and therefore will peck and pull feathers continually until they have succeeded (Leighton et al., 1985).

The behaviour of turkeys which have been beak trimmed has not been investigated to any great extent. Male turkey poults which were arc beak trimmed 1.5mm from the nostril at the hatchery had a slight increase in time spent feeding at two weeks of age, likely because this is when the tip of the beak falls off, making it more difficult for the birds to grasp the feed crumbles (Noble et al., 1996b). No other behavioural differences were noted, except for an increase in time spent standing in the week of hatching in beak trimmed turkeys.

<u>Ability to heal:</u> Beak trimming with an electric current at one day of age in turkeys caused extensive damage to the beak, more so than secateurs or a heated blade (Gentle et al., 1995). Turkeys trimmed with secateurs showed little underlying damage 24 hours after trimming. Trimming with a hot blade caused a variable amount of damage, depending on the temperature of the blade and the time of contact with the beak (Gentle et al., 1995). At 21 days after trimming, extensive healing and regrowth was noted in all types of trimming and in turkeys beak trimmed with a secateur or a hot blade, the stump had healed completely (Gentle et al., 1995). By day 42 beaks trimmed with an electric current appeared normal but shorter than birds with untrimmed beaks while the secateur and hot blade trimmed beaks appeared similar to untrimmed beaks but the tip remained without innervations (Gentle et al., 1995). There was a lack of innervation found in the regenerated trimmed beaks, but neuromas were not found either (Gentle et al., 1995).

TOE TREATMENTS

Toe clipping (with the goal of removal of the toe nails at hatching) is used in commercial turkey production to reduce the number and severity of scratches and scars present on the carcasses. The number of toes which are clipped varies among producers and bird sex, as does the location of clipping. Toe trimming is also performed in male broiler breeders to prevent them from damaging the females during mating. The hallux is generally cut at the hatchery from a normal length of 7-8mm to 3.5-6.0mm (Gentle & Hunter, 1988). Microwave toe trimming has been used where the toes are treated with microwave energy for a short time (0.8 seconds) to restrict the growth of claws (Wang et al., 2008). Toe clipping has also been performed by surgical scissors or sharp instruments or a hot blade (Owings et al., 1972); however, these methods are not in use for commercial birds in Canada.

Performance characteristics: Turkeys with untrimmed toes were nearly half a kilogram heavier at 17 weeks of age than those with trimmed toes (trimmed using a hot blade) (Newberry, 1992). Feed intake was also higher in turkeys with untrimmed toes, while feed conversion was not impacted (Newberry, 1992). In contrast, no effect of toe clipping was found on weight or feed efficiency of poults at 24 weeks of age with 3 toes clipped behind the toe nail on each foot at 1 day of age (Owings et al., 1972). Turkey poults with three claws on each foot clipped off proximal to the toe nail with surgical scissors at hatching did not differ from unclipped turkeys in weight or feed conversion at 9 weeks (Proudfoot et al., 1979).

Mortality was higher in the first 4 weeks of rearing in turkeys which had their toes trimmed in comparison to those which didn't, but total mortality to 17 weeks of age was not affected (Newberry, 1992). During the first week, mortality of toe clipped turkeys was nearly 10%, compared to less than 2% in unclipped turkeys, although no explanation was given for this difference (Owings et al., 1972). The incidence of starvation as a cause of death was over twice as high during the first four weeks in turkeys with trimmed toes compared to those with intact toes (Newberry, 1992). Poults which were toe clipped were observed to move very little in the first three days which may have affected their ability to consume adequate feed and water, although this observation was not quantified (Owings et al., 1972).

Physiological healing (stress measurements): Microwave toe trimming of three toes at one day of age did not influence long-term stress measurements. Heterophil to lymphocyte ratio was also not impacted by microwave toe trimming when measured at 21 and 35 days of age (Wang et al., 2008). It is possible that there is shorter term stress induced by toe trimming but that these effects were not measured.

Time of healing: In broiler breeders whose toes were trimmed using cutting at the hatchery, healing was complete at 22 days after amputation (Gentle & Hunter, 1988). Small neuromas were found where regenerating nerves were trapped in scar tissue when a cutting procedure was used (Gentle & Hunter, 1988).

Carcass damage and grading results: In order to qualify as a Grade A carcass, turkeys must have a carcass free of lesions and blemishes. The grade can be reduced by bruising, skin tearing, skin infections or ulcers, severe scratches, leg or wing fractures and other defects (McEwen & Barbut, 1992). Scratches may be painful, and in severe cases may be considered a welfare issue. Turkey hens which were toe clipped at one day of age with a hot blade averaged higher percentage of Grade A market grades (Greene & Eldridge, 1975). Toms from groups which had 3 toes clipped averaged a higher percentage of Grade A than those with 2 toes clipped which averaged more than those with no toes clipped (Greene & Eldridge, 1975). A survey of three processing plants found that an equal or greater percentage of toe trimmed turkeys were graded A compared to untrimmed turkeys, but the significance of the difference varied with plant, year and sex of the birds (Owings et al., 1972).

A survey of turkeys at an Ontario processing plant found that more leg and breast scratches were associated with the number of toenails trimmed; untrimmed turkeys had more scratches than birds with two trimmed toenails which had more scratches than those with three toenails trimmed (McEwen & Barbut, 1992). Spur clipping was also associated with reduced number of back scratches (McEwen & Barbut, 1992). Condemnation rate was found to be similar between turkeys that were toe clipped and those that weren't (Owings et al., 1972).

Leg weakness: A case report (Alfonso & Barnes, 2006) described leg weakness during the first week post-hatch in female turkey poults with toes 2-4 trimmed by microwave and toe 1 trimmed by hot blade at the hatchery. The toe trimming was thought to provide an avenue of entry for *Staphylococcus aureus* which then spread to the joints and bones of the leg. Enlarged and swollen feet, tendons and joints and leg weakness, along with dehydration and starvation led to increased mortality.

Infectious disorders. Trimming toes may provide a portal for entry for certain bacteria if cauterisation of the wound is not complete. An isolated outbreak of erysipelas infection found in turkey hen poults was thought to originate through injured toes due to improper use of a microwave toe-trimming device (Hollifield et al., 2000). Improper cauterisation of toes may have allowed the organism to enter the wound, and the toes that were microwaved were reported to be macerated and necrotic (Hollifield et al., 2000).

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