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The contribution of environmental enrichment to sustainable poultry production

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Abstract

Environmental enrichment comprises stimuli added to the poultry housing environment to enhance the biological adaptation of the birds and improve their welfare. By promoting species-typical behaviour, it has the potential to reduce the risk of harmful behaviours and health conditions, and to guide birds to use the available resources more uniformly. Environmental enrichment may also promote positive emotional states and enhance the birds' ability to cope with unpredictable environmental changes. In this chapter, we review environmental enrichment strategies that are relevant to commercial meat poultry production, their benefits in terms of the behaviour and welfare of the birds and their potential for contributing to more efficient and sustainable production models. Potential risks or problems that may arise when environmental enrichment is not appropriately implemented are also discussed, finishing with discussion of current gaps in knowledge and concluding remarks.

Keywords: Environmental enrichment, environmental complexity, poultry welfare, poultry health, poultry behaviour, stress resilience

Contents:

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1. Introduction

Extraordinary progress in poultry production efficiency has been achieved through advances in genetics, nutrition and animal health. New technology has permitted major improvements in control of the housing environment. Despite this success, the poultry industry faces new and important challenges that are no longer based solely on improving productive efficiency. Contemporary poultry production must still maintain competiveness but must also consider ethical and social responsibility factors that influence consumer acceptance such as food safety, environmental impact and animal welfare. These are key aspects to ensure the long-term sustainability of the poultry industry.

Any sustainable system must respond to consumer demands for farming methods that are based on the respect and ethical treatment of the production animals. Therefore, consideration of animal welfare is an inherent aspect of any sustainable production system. No less importantly, improving animal welfare can also contribute to the reduction of system inefficiencies by promoting healthier and more efficient animals that are better prepared to confront stress challenges and disease threats. These animals should also require less medication. Thus, better welfare can result in more efficient (higher production outputs with a similar use of resources or inputs) and socially responsible methods that are in line with consumers' ethical considerations and demands.

There have been notable advances in our knowledge about the behaviour and welfare of meat poultry, especially chickens (e.g. Dawkins, 2004; Estevez, 2007). A key advance has been in the area of environmental enrichment, a concept referring to additions and modifications to the production environment that facilitate the biological adaptation of the animals to their environment and improve their welfare (Newberry, 1995). A variety of welfare benefits can be targeted, such as better health, promotion of positive emotional states and increased stress resilience. Various studies have remarked on the positive effects of environmental enrichment strategies to control unwanted behaviours, promote adaptive behavioural responses, improve welfare and maximize productive efficiency in poultry (e.g. Cornetto and Estevez, 2001; Leone and Estevez, 2008; Estevez, 2009; Ventura et al., 2010, 2012).

Despite these advances, the implementation of environmental enrichment at a commercial level has been limited. This response is driven, in part, by the assumption that addressing behavioural needs and animal welfare leads to higher production costs and less competitiveness. This may be the case in situations involving major structural modifications to the housing, or the banning of a production system as has happened in European Union countries due to legislative requirements (Directive 1999/74/EC). However, environmental enrichment strategies can be cost-effective and beneficial to both the birds and the producers. For example, Leone and Estevez (2008) demonstrated that a $400 investment to outfit a standard commercial broiler breeder house with short vertical 'cover panels' made with plastic netting resulted in a $6304 return on investment due to an increment of 4.5 more chicks produced per female in a single production flock. This is just one illustration of the potential of environmental enrichment.

The use of different forms of environmental enrichment has usually occurred in response to the need to reduce a health problem that has a negative economic impact. For example, a high incidence of leg problems in meat poultry is a serious welfare concern (Marchewka et al., 2013, 2015) that causes major economic losses. The reduction in production efficiency not only relates to the mortality caused by leg problems, often in birds close to market weight, but also to increased downgrades and condemnations associated with lameness and immobility as demonstrated in turkeys (Marchewka et al., 2015). It is speculated that the low activity observed in broiler chickens (Newberry et al., 1985; Weeks et al., 2000) may influence the incidence of leg problems. Newberry (1999) showed that environmental enrichments that stimulate exploration increase the birds' motivation to move and use the available space. The provision of key elements in the environment that motivate the birds to move may help to reduce the incidence of leg problems, thus achieving more sustainable production in the longer term.

Feather pecking and cannibalism are unwanted behaviours that have a catastrophic impact on the welfare and performance of poultry. Limited opportunities to explore and forage early in life may lead to feather pecking and cannibalism, although it is recognized that these behaviours have a multifactorial origin (Newberry et al., 2004; Drake et al., 2010; Nicol et al., 2013; Estevez, 2015). They are more typically found in laying hens, especially in alternative egg production (Green et al., 2000), and are uncommon in broilers. However, they occur occasionally in slow-growing meat chicken strains (Nielsen et al., 2003), while turkeys (Marchewka et al., 2013), ducks and broiler breeders are often beak trimmed to prevent them from developing. Though beak trimming is administered to prevent major welfare problems, this practice raises ethical concerns to the point that it is banned in some European countries, and others envision it being banned for all poultry species in the near future. It is important to be able to provide the means to reduce the incidence of feather pecking and cannibalism through alternative strategies, such as environmental enrichment, because banning of beak trimming or unacceptance of this practice by consumers is likely to extend globally.

Environmental enrichment strategies incorporate elements into commercial housing that are key to promoting normal behavioural development and facilitating adaptation to the physical and social environment. By considering these aspects, it should be possible to minimize problems that are costly in terms of animal welfare but that also cause important losses in productive efficiency (e.g. recurrent panic attacks leading to crowding and suffocation at specific locations that may result in high mortality). For birds such as broiler breeders that are reared in a bi-dimensional environment and later moved to a three-dimensional production environment, facilitating their transition to the latter is particularly relevant (Estevez, 2009). There is a diversity of options to incorporate simple changes in the housing environment to help birds cope better with the physical and social environment. These approaches can spare birds unnecessary stress while also rewarding farmers with higher productive efficiency.

In this chapter, we review environmental enrichment strategies that are relevant to commercial meat poultry production, their benefits in terms of behaviour and welfare of the birds and their potential for contributing to more efficient and sustainable production models. Potential risks or problems that may arise when environmental enrichment is not appropriately implemented are also discussed, finishing with discussion of current gaps in knowledge and concluding remarks.

2. Structural complexity: an introduction

Natural environments offer a wide range of structures used by animals for different purposes. Environmental features such as cover provided by bushes, rocks and uneven terrain offer protection from adverse weather conditions, predators and aggressive conspecifics (Elton, 1939), thereby reducing the need for vigilance (Lazarus and Symonds, 1992). Elevated structures and tree branches are used by the domestic fowl under natural and semi-natural conditions to perch during the day and to roost at night (Wood-Gush et al., 1978; Blokhuis, 1984), suggesting that perching provides an increased perception of safety (Newberry et al., 2001). Environmental complexity also serves to reduce visual contact between conspecifics (Estep and Baker, 1991) which, in chickens, helps to prevent, or terminate, aggressive interactions (Cornetto et al., 2002) and coercive mating (Pizzari, 2016).

In contrast, commercial meat poultry are typically raised in large open houses with little option for moving to protected areas if feeling threatened, to rest undisturbed, or to ascend to an elevated structure to roost at night. We can speculate that because of the unlikelihood of predation occurring in the indoor production environment, there is no need to offer structurally complex indoor environments. However, the need for protection against predation has shaped behaviour in the ancestors of our current poultry species across thousands of years of evolutionary pressure. Although genetic selection has indeed altered the behaviour of poultry, these changes appear to relate more to quantitative than to qualitative aspects (Newberry, 2017a). Behavioural strategies that were critical for survival under natural conditions are especially likely to persist, even in highly selected genetic production lines (Pizzari, 2016). Behaviour such as perching (Newberry et al., 2001) and the use of cover (Newberry and Shackleton, 1997; Cornetto and Estevez, 2001a) to avoid predation, and variation in competitive behaviour for access to basic resources according to the resource distribution (e.g. food, Leone and Estevez, 2007; mating opportunities, Bilcik et al., 2005) are easily observed in commercial poultry. These behavioural responses are not problematic in themselves as long as birds have adequate environmental features to allow them to respond appropriately, thus minimizing the risk of problematic behaviours and costly stress responses (Jones, 1996).

The addition of different forms of enrichment that provide structural complexity (e.g. perches, ramps and cover panels) in commercial meat poultry houses can be cost-effective to resolve or minimize behaviour-related management and welfare problems. These structures create microenvironments within the production house facilitating the birds' adaptive behavioural responses. If birds are able to modulate their responses, or avoid overexposure to social contact, stress levels should be minimal, permitting birds to maximize their investment of resources in growth and reproduction.

3. Structural complexity: cover panels

3.1. Promoting uniform distribution of birds throughout the house

A mismatch between the birds' behaviour and the characteristics of the production environment may be the source of costly mortality due to panic reactions, even in apparently apathetic broiler flocks. The natural flock reaction when a danger is perceived is to seek cover. Thus, birds will run to the nearest (and only) cover, usually the end wall, where they cluster. In severe cases of panic, several thousand birds may die as a consequence of piling up against walls. Short vertical 'cover panels' distributed along the house can provide cover that shelters birds from the perceived danger (Newberry and Shackleton, 1997; Cornetto and Estevez, 2001a, b), stopping birds in smaller groups along the house before a large number reach the end of the house where they pile on top of each other, risking scratches from each other's claws, overheating and suffocation. Vertical cover panels can be constructed with a frame of wood, PVC piping or other materials, supporting a screen of plastic netting or similar material that partially obstructs the vision of the birds without impeding ventilation (Fig. 1).

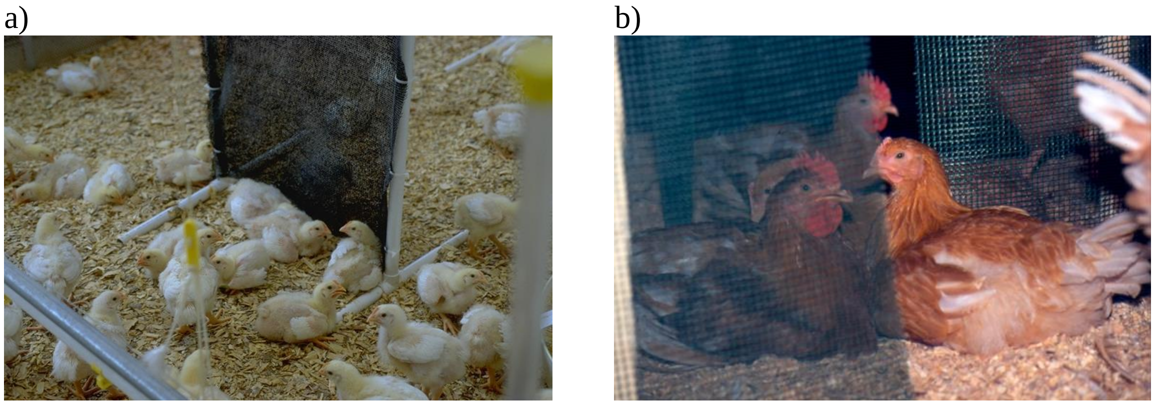

Figure 1. *Broiler chickens resting by vertical mesh cover panels providing partial visual cover in the central area of the house. a) Photo: I. Estevez, b) Photo: R. C. Newberry.*

A homogeneous bird distribution along the house is desirable to facilitate uniform use of resources and a homogeneous airflow among birds. However, birds tend to be found at relatively high density along the walls, while central areas may be relatively underused (Newberry and Hall, 1990). Although the effects of uneven flock distribution are difficult to quantify, they may have an important impact on sustainability. Uneven flock distribution may result in compromised welfare and lower productive efficiency and may even affect food quality (Cornetto and Estevez, 2001a). By limiting airflow around birds, higher than desirable bird density at specific locations increases heat stress in hot weather. Litter condition may deteriorate faster in highly used areas adjacent to walls, increasing the risk of footpad dermatitis (De Jong et al., 2014), one of the most clear indicators of compromised welfare in broiler chickens (Welfare Quality, 2009). As birds move in and out of highly populated areas, they may bump into or step on other birds rather than manoeuvring around them (Estevez, 1994), causing disturbance of resting birds (Cornetto et al., 2002). This behaviour not only disrupts resting periods that are important for physiological processes such as sleep, tissue restoration and growth (Blokhuis, 1984), but may also increase the risk of skin scratches and bruises to the birds that are disturbed. Under experimental conditions, the use of vertical cover panels to distribute birds more evenly has been found to reduce the frequency of disturbances and promote resting and preening within central areas of the house (Newberry and Shackleton, 1997; Cornetto and Estevez, 2001a,b; Cornetto et al., 2002; Fig. 2).

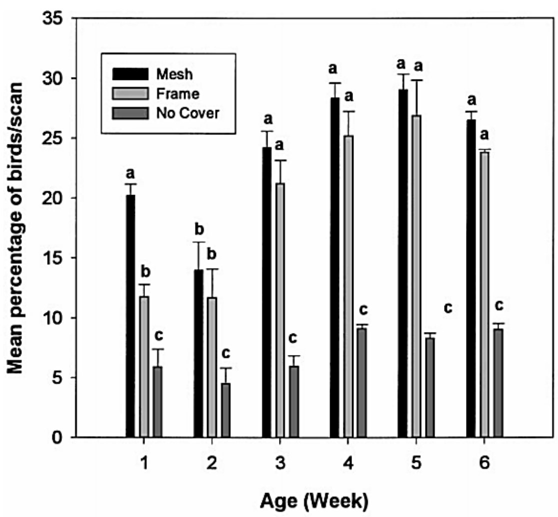

Figure 2. *Mean percentage of birds using the central region in enclosures enriched with vertical mesh cover panels (black) or panel frames without mesh (grey) as compared to control (no cover) enclosures (dark grey). Treatments with different letters denote statistical differences (P<0.05). From Cornetto and Estevez (2001a).*

Enrichment of the indoor housing of commercial slow-growing broilers with cover panels has also been effective in promoting a more even bird distribution, although no further benefits were detected in regard to behavioural changes or use of an outdoor area (Rodriguez-Aurrekoetxea et al., 2014; Rodriguez-Aurrekoetxea and Estevez, 2015).

Although cover panels are not typically used in commercial conditions, it is not uncommon to find the use of straw bales (Fig. 3) or wood shavings bales in chicken houses, especially in European countries. This simple enrichment has a similar function to cover panels in providing protection to the birds while also offering opportunities for the more audacious birds to perch and forage. The bales disintegrate into the litter at a rate that depends on whether or not they are wrapped in plastic that prolongs their integrity, and on the number of bales provided. The bales may help to maintain better litter condition, by adding dry material to the existing litter. Apart from collecting the plastic wrap, they do not require any additional cleaning or maintenance effort as new bales are added with the new flocks. However, in one of the few studies on the effects of straw bales under commercial conditions, Bailie et al. (2013) reported only minor increases in locomotion, standing and latency to lie down, which were interpreted as indicating better leg condition. The congregation of birds around the bales suggests that the bales were acting as a form of cover. Despite positive indications, benefits may be limited by the sparsity of bales typically provided relative to the dimensions of chicken houses and the large number of birds housed (Bailie et al., 2013), although Bailie and O'Connell (2014) did not detect benefits from adding more bales.

Figure 3. *Broilers using straw bales for roosting, foraging and as cover. Photo: R. C. Newberry.*

3.1.1. Benefits of cover panels in breeding flocks

Substantial female mortality occurs in broiler breeder flocks as a result of male harassment and forced mating (Fig. 4), especially in situations of high male–male competition for access to females (Estevez, 1999; Pizzari, 2016).

Figure 4. *Female broiler breeder with injuries due to forced matings. Photo: I. Estevez.*

Placing cover panels along the litter area successfully controlled ongoing female mortality in a problematic commercial flock by attracting a larger number of females down from the slatted area to the litter area (Fig. 5), thus reducing male–male competition for females (Estevez, 1999). The presence of cover panels (or structures such as straw or hay bales) may also act to reduce the visibility of females in the litter area, thereby diminishing mating pressure.

a) b)

Figure 5. *a) Broiler breeder males in the litter area, with a low number of females; b) the same litter area 24 h after introduction of cover panels. Note the difference in the number of females. From Estevez (1999).*

It might be speculated that, if mating pressure declines, the presence of structural complexity in the mating area would have a negative impact on fertility, which is, in itself, a relevant performance issue in broiler breeders (McGary et al., 2002). Follow-up studies conducted by Leone and Estevez (2008) in commercial breeder flocks showed that, on the contrary, females in houses enriched with cover panels laid 2% more eggs than females in unenriched houses, and both flock fertility and hatchability were improved in enriched flocks. Enriched and control flocks started to diverge at around 35 weeks of age, when flock fertility started declining. The improved reproductive performance may be due to a combination of factors such as reduced stress, reduced male–male competition and lower mating interference. A higher proportion of successfully completed matings is one of the factors speculated to promote fertility in broiler breeder flocks (Bilcik and Estevez, 2005; Bilcik et al., 2005). It was also observed that, although males varied in the size of their home ranges, they generally used a higher proportion of the available space when the house contained cover panels (Leone and Estevez, 2008). Their greater roaming behaviour increased the possibility of mating with a larger number of different females along the house.

As indicated above, the economic revenue was increased by over $6000 in a single flock with an initial investment of $400 (Leone and Estevez, 2008). This is probably one of the best examples for understanding how environmental enrichment techniques can help to improve the health and welfare of the birds while also boosting economic returns, and probably the degree of work satisfaction of the producer.

3.2. Findings on cover in other meat poultry species

Although there have been few studies on environmental enrichment in meat poultry species other than chickens, there are a couple of examples of the use of structures similar to cover panels. Sherwin et al. (1999) observed a decline in injurious pecking and a possible improvement in musculoskeletal function in male turkeys reared under experimental conditions when provided with structures offering cover. Deeming et al. (2011a,b) observed that both male and female pheasants had better feather condition at the end of the breeding season in pens with visual barriers as compared to controls. Deeming et al. (2011b) also showed that, although barriers did not affect the frequency of courtship and mating, they did reduce the frequency of aggressive pecks and chases in pheasants. Fertility was also significantly higher and persisted for longer in the pens with visual barriers as compared to the controls, similar to the findings of Leone and Estevez (2008) in broiler breeders.

The consistency of results across meat poultry species suggests that cover panels serving as partial visual barriers offer a simple and cost-effective type of enrichment that facilitates the birds' adaptation to commercial facilities according to their behavioural biology. The addition of cover panels results in fewer behavioural problems such as disturbances, aggressive interactions and sexual harassment while improving fertility and hatchability in breeding flocks. Other effects such as protection against fatalities resulting from panic reactions are difficult to test but likely to be beneficial. Thus, increasing the level of visual cover could have a significant impact in improving welfare and bird performance, thereby contributing to long-term sustainability.

4. Structural complexity: perches, barriers and ramps

Perches are provided to satisfy the natural motivation of domestic fowl, turkeys and pheasants to roost in safe, elevated locations (ancestrally, in trees) throughout the night and for shorter periods during the day (Collias and Collias, 1967; Wood-Gush et al., 1978; Blokhuis, 1984). Perches offer birds opportunities to jump on and off them, which is known to improve bone strength and reduce the risk of osteoporosis in laying hens (e.g. Tauson, 1984; Appleby et al., 1992; Leyendecker et al., 2005). From a functional standpoint, accessing the third dimension permits laying hens to avoid cannibalism, feather pecking (Huber-Eicher and Audige, 1999) and aggressive individuals (Cordiner and Savory, 2001). These benefits are likely to be similar in meat poultry in which feather pecking and aggressive interactions occur such as in turkeys (Marchewka et al., 2013). The use of perches appears to increase perceived safety (Newberry et al., 2001). When used from an early age, the experience manoeuvring in three dimensions improves the birds' spatial skills (Gunnarsson et al., 2000). It also increases the use of nest boxes, reducing the incidence of floor eggs in laying hens (Gunnarsson et al., 1999) and broiler breeder flocks (Brake, 1987; Appleby et al., 1988).

Because of the demonstrated benefits for the health and welfare of laying hens, current European legislation (Directive 1999/74/EC) requires that a minimum of 15 cm of perching space per hen is provided in commercial egg-producing systems for adult laying hens within EU countries. This legal requirement contrasts with the situation for commercial meat poultry where perches are not usually provided. This difference may relate to the low use of perches found in some studies on perching behaviour of young broilers (Fiscus Le Van et al., 2000; Martrenchar et al., 2000; Pettit-Riley and Estevez, 2001; Kaukonen et al., 2016). Additionally, broilers are often slaughtered prior to the age when jungle fowl would start to be brooded in trees under natural conditions, suggesting that they may not have a strong motivation to roost on perches. They also have relatively ample space to move around on the floor until the last week of the rearing period. These conditions may have contributed to the perception that perches are not necessary for broilers. Nevertheless, crossing obstacles, exploring in low undergrowth and sitting on low structures are components of their natural behaviour, and studies with different perch designs indicate that enrichment of broiler houses with perches may, in fact, be advantageous from health, welfare and performance points of view.

Several studies concerning potential benefits of perches for meat poultry have been conducted in broilers under simulated commercial management conditions. Perch use in these studies has varied depending on factors such as perch design (length, height, material, shape, disposition and location), bird age and environmental factors (Koene et al., 1999; Martrenchar et al., 2000; Su et al., 2000). For example, less than 1–7% of the flock perched on angled and 8.5-cm-high horizontal perches (Fiscus Le Van et al., 2000; Pettit-Riley and Estevez, 2001), and from 7 to 27% on perches set 15–30 cm above the floor (Hughes and Elson, 1977; Bizeray et al., 2000; Ventura et al., 2012; Kiyma et al., 2016), although Norring et al. (2016) noted very low use of 10- and 30-cm-high perches. Peak perch use usually occurred at around 3–5 weeks of age, declining thereafter. However, Estevez et al. (2002) observed that the use of 15-cm-high perches increased from 4 to 6 weeks, while the use of 7.5-cm-high perches declined during this period. Their study was conducted in midsummer to test the effectiveness of cool perches (i.e. perches constructed from pipes refrigerated by cooled water circulating through them) to reduce the effects of heat stress. It is likely that the relatively high perch use was due to increased cooling when perched on the higher perches and, especially, on the cool perches.

Access to elevated platforms is an alternative to perches that may also act as a form of cover. Although the information available is limited, Norring et al. (2016) noted a higher use of platforms as compared to perches.

4.1. Benefits of using the third dimension

Even though the volume of research on perch use in broilers is not as ample as for layers, improvements in health and welfare as well as product quality and production efficiency have been identified. Bizeray et al. (2002a,b) used perches (100 cm long by 4 cm wide by 15 cm high) serving as barriers between feeders and drinkers to stimulate locomotion in broilers, with the aim of reducing the incidence of leg problems (Fig. 6). Although access to barrier perches did not have a detectable effect on gait score (assessed according to Kestin et al., 1992), bone quality or amount of walking, birds reared with barrier perches had wider tibias. This effect was probably related to perching behaviour as birds spent nearly 10% of the photoperiod perching at the expense of reduced time spent lying on the litter. Considering that broilers were observed to spend 60–80% of their time resting during the photoperiod (Cornetto and Estevez, 2001b), a 10% reduction in the time spent in contact with litter by resting on perches may be beneficial. In fact, follow-up studies by Ventura et al. (2010, 2012) and Kiyma et al. (2016) demonstrated that birds provided with barrier perches had a lower incidence of foot pad dermatitis. Furthermore, in commercial broilers raised with elevated platforms, Kaukonen et al. (2016) reported a reduced incidence and severity of tibial dyschondroplasia, and a lower mean percentage of birds with gait score 3 (moderate gait abnormality), though no differences in higher gait scores indicating severe leg problems.

Figure 6. *Four-week-old broilers using barrier perches (from Bizeray et al., 2002a, b).*

Access to the third dimension provides some additional benefits. Ventura et al. (2012) found a lower frequency of resting disturbances (i.e. interruption of resting due to disruption caused by the action of another bird; Cornetto et al., 2002), especially at high rearing densities (Fig. 7).

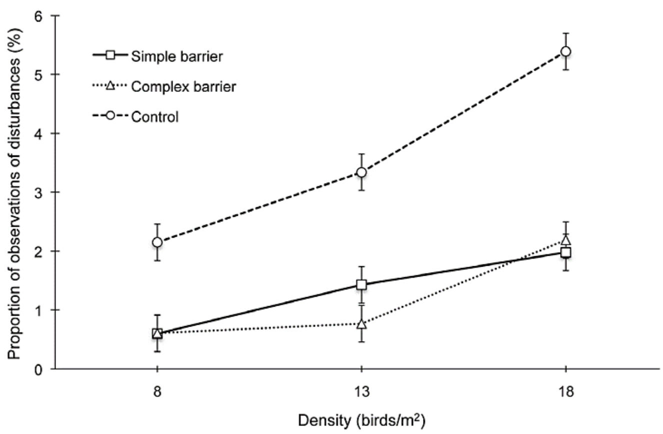

Figure 7. *The effect of access to single (simple, continuous line) and double (complex, dotted line) barrier perches or no access to perches (control, dashed line) on the proportion of observations with disturbances (i.e. resting birds getting up due to jostling by active birds) at three bird densities. From Ventura et al. (2012).*

Reduced disturbances could contribute to bird health and production efficiency by minimizing the risk of skin scratches, thereby lowering the incidence of downgraded carcasses. Ventura et al. (2012) also observed higher use of the central areas in pens with barrier perches, indicating that they contributed to a more homogeneous bird distribution and therefore to a more uniform use of resources. Similarly to cover panels, barrier perches may also be helpful in controlling panic reactions.

One of the arguments against the implementation of perches in commercial conditions is the potentially added cost of higher feed consumption due to increased activity. However, there was no evidence of increased feed conversion ratios or reduced body weights in studies where broilers had access to perches (Pettit-Riley and Estevez, 2001; Bizeray et al., 2002b; Ventura et al., 2010; Kiyma et al., 2016), even when perching reached as high as 25% of the time budget (Ventura et al., 2012). Any increase in energy expended climbing on and off perches may be compensated by a reduction in running and aggressive interactions (Ventura et al., 2012). Availability of perches may be particularly beneficial at high densities when walking is obstructed, and lying on the floor is increasingly disrupted (Buijs et al., 2011). Perches are not only effective at reducing the frequency of disturbances contributing to better quality rest (Ventura et al., 2012), but could reduce skin damage related to deteriorating litter condition at high densities (Estevez, 2007). A further potential benefit of perches may be reduced injuries during catching and shackling, considering that perch access resulted in less wing flapping by broilers when caught and suspended by the legs (Newberry and Blair, 1993).

The scientific literature for other meat poultry species in regard to the potential benefits of perches is limited. In turkeys, Martrenchar et al. (2001) reported a peak in perching in Week 5, with 10–13% of birds perching, declining to 0 by Week 10. They also found reduced injurious pecking in this treatment as compared to the control. However, besides perches, the pens were also enriched with bright pecking objects and straw, making it unclear whether the effects were due to the availability of perches, the diversion of attention towards the other enrichment elements or a combination of both. Bergmann et al. (2001) observed more use of perches and platforms by free-range turkeys during the night than during the day. In pheasants, those reared in pens with perches were more likely to use elevated roosting sites after release on hunting estates, and had lower juvenile mortality due to natural causes, than controls reared without perches (Whiteside et al., 2016).

4.2. Perches and the thermal environment

Any opportunities for the birds to get off the litter for extended periods by using perches or platforms gives birds more options for behavioural thermoregulation. Studies on laying hens and broiler breeder females (Muiruri and Harrison, 1991; Muiruri et al., 1991) and broiler chickens (Reilly et al., 1991; Estevez et al., 2002) have shown that the birds prefer to roost on cold perches when exposed to high environmental temperatures. These results indicate that birds actively used cool perches for thermoregulatory purposes, helping to reduce heat stress and thereby improving egg production and hatchability of broiler breeders (Muiruri and Harrison, 1991), and increasing final body weights and feed efficiency in broiler chickens (Reilly et al., 1991; Estevez et al., 2002). No panting was observed in broiler breeder hens with access to cool perches, even when temperatures reached as high as 40 C (Muiruri et al., 1991). This result suggests that cool perches are effective at controlling heat stress, probably at a lower energy cost and avoiding the inconvenience of wetting of litter caused by some cooling systems used in commercial broiler breeder houses. Although the number of experimental studies is limited, and no studies have been conducted under commercial conditions, the results suggest that perches that stimulate exercise in the third dimension may also provide a cost-effective alternative for optimizing the thermal environment through cooling, and also potentially warming, opportunities.

5. Other benefits of structural complexity

5.1. Acquiring navigational skills for the future

Research has shown that early life experience can have an important effect on behavioural and neuronal development, use of space and learning ability in mammals (Rosenzweig and Bennett, 1996; Chaloupkova et al., 2007) and in the domestic fowl (Gunnarsson et al., 2000). When birds are maintained in a different environment during rearing (typically a bi-dimensional environment) than during the reproductive period (typically a more complex, three-dimensional environment), the transition between environments can be stressful (Hocking et al., 2005) until the birds get acquainted with the physical and social features of the new environment. The same applies to preparation of young birds for success in free-range conditions. The difficulty adapting will be more severe the larger the disconnect between environments. Access to perches or any elements that confer young birds with the opportunity to experience the third dimension and to navigate in a more complex environment (e.g., cover panels) can help them to acquire essential skills that facilitate their transition between environments. For example, pheasants reared with perches made fewer errors in finding food than controls without perches when tested in an eight-arm radial maze, which was relevant to their subsequent survival when released outdoors (Whiteside et al., 2016).

One of the main differences between the rearing and the egg production environment is that, in the latter, feeders, drinkers and nest boxes are elevated above the floor. It may take some days for the birds to learn to locate and use them, especially considering that feeders and drinkers may be of different types than provided during rearing, and the birds have never previously been exposed to nest boxes. Due to the birds' failure to find and use nest boxes, it is quite common to have a high incidence of floor eggs in breeding flocks during early lay (Appleby et al., 1988; Estevez, personal observations). This problem is often managed by fencing the females on the slatted area for several days hoping that they learn to lay the eggs in the nest boxes. However, this practice can be stressful for the birds leading to reduced performance, and it requires additional work (and cost) for the farmer. Providing early access to perches, ramps and platforms should facilitate transition to the laying house without the need for confinement on the slats as birds will be better prepared to jump on and off heights and to explore in three dimensions.

Although limited data are available for meat poultry, both Brake (1987) and Appleby et al. (1988) reported that broiler breeders reared with perches had around 5% fewer floor eggs when reared with access to perches. Appleby et al. (1988) reported that 86% of control hens laid their first egg on the floor whereas for hens reared with access to perches this proportion was reduced to 21%. Differences in the rate of floor eggs between birds reared without perches or with access to perches starting within four weeks post-hatch were evident up to 35 weeks of age in layers (Gunnarsson et al., 1999) and appear to have persisted to 40–50 weeks in broiler breeders (Brake, 1987). These results illustrate the role of learning in the utilization of nest boxes and the long-lasting effect of providing birds with early access to perches or other elevated structures such as ramps or platforms.

Preparedness for the new environment does not require that young breeders are reared under exactly identical conditions to the ones they will experience later in life. It has been argued that providing young birds with the opportunity to explore an enriched, variable environment in which to develop their cognitive skills can also improve their welfare (Meehan and Mench, 2007). For example, the skills required to adapt to the breeding facility can be acquired when young birds are provided with opportunities to learn the spatial competencies necessary to navigate and access resources. These opportunities could include the provision of cover panels in the rearing facility (Newberry and Shackleton, 1997; Cornetto and Estevez, 2001a), potentially improving the birds' ability to get around obstacles. Research has also shown that poultry species use visual cues not only to locate food resources but also to exploit them more efficiently, especially in changing environments (Vallortigara, 1996; Roper and Marples, 1997). It should be possible to use this learning capacity to our advantage to ease the transition of breeders from rearing to breeding facilities. How broiler breeders and other poultry are raised when young will have long-lasting effects on their behavioural flexibility and stress resilience that will be reflected in their health and performance during their reproductive life. Investment in enriching the rearing environment to prepare young breeders for their reproductive life could, thus, pay off from both the welfare and economic standpoints.

5.2. Dark brooders

Although fast-growing broiler chickens have a low propensity to feather peck, slow-growing broilers do show this behavioural problem occasionally (Nielsen et al., 2003). Other meat poultry, such as turkeys or broiler breeders are often beak trimmed to prevent injurious feather pecking. However, this management practice is stressful for the birds, even if performed within the ten first days of life, a reason why this management practice has already been banned or is expected to be banned in some European countries. Thus, non-invasive strategies must be developed to prevent injurious feather pecking and cannibalism.

Although most environmental enrichment practices will serve to reduce the incidence of feather pecking and cannibalism by, for example, reducing visual (cover panels) and physical contact (perches) with resting birds, dark brooders offer an additional approach for minimizing the risk. Early rearing with dark brooders as compared to regular heating lamps (Johnsen and Kristensen, 2001) gave excellent preliminary results in controlling severe feather pecking, improving feather condition and reducing mortality in layer pullets observed up to 23 weeks of age (Jensen et al., 2006). Similar results were obtained by Gilani et al. (2012) in a study of small commercial flocks of Columbian Blacktail chickens with intact beaks. The birds raised with dark brooders had a lower incidence of severe feather pecking, were less likely to have missing feathers and were slightly heavier. In addition to reducing early feather pecking and stimulating foraging and dustbathing, Riber and Guzman (2016) also obtained evidence suggesting that dark brooders reduced fearfulness in layer chicks. Although so far no studies have been conducted to assess potential application to turkeys, broiler breeders or other meat poultry species at risk of severe feather pecking and cannibalism when beaks are left intact, environmental enrichment with dark brooders may yield welfare and performance benefits in the meat poultry industry as well.

6. Visual enrichment through lighting

Poultry species, with the exception of emus and tinamous, have four cone types supporting colour vision across a broad spectrum extending to the near-ultraviolet range (Hart et al., 1999; Wright and Bowmaker, 2001). However, meat birds are usually kept at low light intensity under unvarying lighting conditions with the intention of minimizing the risk of cannibalism and feather pecking, and maximizing conversion of feed to growth as opposed to diversion into energetically costly behavioural activities. However, dim artificial lighting impairs discrimination between colours (Olsson et al., 2015), ability to navigate between perches (Taylor et al., 2003) and social recognition (D'Eath and Stone, 1999), suggesting that welfare may be enhanced by providing a more varied and dynamic visual landscape.

Bizeray et al. (2002a) used a disco ball to project brightly coloured (red, green, blue and yellow) moving light patterns on the floor during four 1-h periods daily throughout rearing of broilers. It was rare for the birds to follow the moving light spots and no pecking at light spots was detected. Foraging and locomotion were unaffected, but the light treatment did increase time spent feeding by comparison with the control condition. Since feed intake and growth were unaffected (Bizeray et al. 2002b), the authors speculated that the increased time at the feeders may have been occupied in increased feed particle selection when eating.

Newberry et al. (1985) found that providing brighter spotlights that alternated from one side of the house to the other every 1–2 hours stimulated movement in male broilers, although without significantly reducing the incidence or severity of leg disorders. Between 4 and 7 weeks of age, birds of certain strains congregated under the lights, whereas for other strains the density was lower under the lights. Above seven weeks of age, the area under the lights had a similar or lower density of birds compared to the darker areas. It was noted that when males engaged each other in non-harmful sparring under the lights, the resulting disturbance cleared the area of other birds. In a study with male turkeys, Sherwin et al. (1999) provided two bright spotlights that switched on for 1–5 min at random times during the photoperiod as part of a complex enrichment treatment that included multiple pecking stimuli. Injurious pecking was reduced relative to the control, and the turkeys appeared to have stronger legs, although it is not known how the spotlights, specifically, may have contributed to these effects. Some welfare guidelines require that bright spots of light in the poultry house are avoided due to concerns that birds might smother when congregating in those spots (Prescott et al., 2003), although no smothering occurred in the above studies. It should also be noted that, when birds are raised at low light intensities, an uneven bird distribution caused by sunlight flooding through ventilation inlets and fans may have a negative impact on performance and welfare (see Section 3.1 above), especially if resting cycles are not synchronized by a long daily scotoperiod.

Some regulations and welfare assurance schemes, nevertheless, require that poultry have access to natural lighting. Brighter intensity lighting can be expected to increase activity levels (Newberry et al., 1988), and early exposure to the varied patterns of lighting resulting from changing weather condition and across time of day should help to habituate birds to such variations. Indeed, Bailie et al. (2013) observed that light intensities were higher in commercial broiler houses allowing natural light to enter through windows, and birds were more active. Importantly, they found that gait scores tended to be lower and latency to lie was higher in birds exposed to natural light through windows, suggesting that the windows were an effective source of visual enrichment. There may be concerns that exposure to natural light through windows would be a risk factor for feather pecking and cannibalism in adult flocks but this was not found to be the case in a study of 81 Swedish layer flocks (Yngvesson et al., 2011). For birds being reared for free-range production, early exposure to natural light is particularly recommended because lighting preference is influenced by experience (Gunnarsson et al., 2008).

7. Foraging enrichments

Foraging behaviour incorporates the travel time taken to find food, the handling time required to catch, extract and process food into a form that can be swallowed and the ingestion time involved in consuming the prepared food. Wild birds generally spend a large part of their day engaged in the travelling and handling components of foraging, which together comprise the appetitive phase of foraging, whereas only a small proportion of each foraging bout is devoted to the consummatory phase. The appetitive phase of foraging includes learning about new sources of food through exploratory and play behaviour, and attraction to food sources discovered by others (i.e. social learning). It also involves using prior learning to recall and navigate to locations where food has previously been found; recognize which items are edible; select appropriate items to meet nutritional needs; and apply skills developed to catch, extract and process them. Understanding the different aspects of the natural foraging behaviour of poultry species provides insights into the features of materials that can be expected to stimulate foraging behaviour. These include a degree of concealment requiring searching and extraction, particle variability that attracts investigation, a degree of movement, manipulability and destructibility providing opportunities to practice food handling skills and edibility providing a consummatory reward.

In modern poultry production, where nutritionally complete, processed feed can be easily found in predictable locations, the demands for appetitive behaviour are minimal. A majority of foraging time is devoted to consummatory behaviour and overall expenditure in foraging behaviour is low. Although domesticated poultry, and especially broilers (Lindqvist et al., 2006), invest less time in foraging than wild birds, they nevertheless exhibit some foraging. Chickens, for example, can be seen pecking and scratching in the litter despite the nearby presence of feeders, investigating novel objects, running into a familiar area accessible for a restricted period each day (Newberry, 1999; Fig. 8), engaging in playful 'worm running' with small objects found in the litter (Cloutier et al., 2004) and jumping to catch insects and seeds swaying in the breeze at the end of stalks. Ostriches given access to sand enriched with cabbage, conifer cones and sticks explored more, pecked more at a novel food source and tended to peck less at pen fixtures than control birds (Christensen and Nielsen, 2004; Fig. 8).

a) b)

Figure 8. a) Heavy broilers running into an area accessible for only 3 hours daily (see Newberry, 1999 for details). Photo: R. C. Newberry. b) Ostrich foraging in sand. Photo: I. Estevez.

The emergence of an outbreak of cannibalism provides a prime example that modern poultry retain the motivation for individual and social learning about new food sources (Cloutier et al., 2002). A major economic incentive for investing in foraging enrichments relates, therefore, to their role in guiding appetitive foraging activities towards appropriate substrates and reducing investigation of conspecific body parts as potential food sources. This is important because even if only one bird in a flock learns through exploration that feathers, eggs, blood or internal organs represent rich food sources, others will be quick to join in, thereby having the opportunity to learn the undesirable behaviour as well (Cloutier et al., 2002). Although unusual in broilers, these redirected foraging behaviours (Newberry et al., 2007) can be a serious concern in turkeys, pheasants, ducks and geese with intact beaks, especially if kept on slatted flooring.

There is limited research on foraging enrichments for poultry species other than chickens but methods found effective for reducing feather pecking and cannibalism in laying hens may be beneficial. First, it is important to rear birds from day 1 with access to litter. Early access to particulate substrate on a solid surface has long-term value in reducing the risk of damaging feather pecking (Tahamtani et al., 2016). However, access to litter alone is insufficient to prevent the development of severe feather pecking in the birds that are most motivated to forage (Newberry et al., 2007). Long-cut straw is an effective foraging enrichment found to retain sustained interest as a foraging substrate and help to reduce the risk of unwanted behaviours in laying hens, as has provision of feed in mash rather than pelleted form (Aerni et al., 2000), and hanging bunches of thick string that can be pulled apart (McAdie et al., 2005). It is suggestive that straw was a component in combined enrichment treatments found to reduce pecking damage in turkeys (Sherwin et al., 1999; Martrenchar et al., 2001). However, Hocking and Jones (2006) detected no improvement in the feather and skin condition of commercial broiler breeders provided with wood shavings bales and bunches of string.

Another goal in providing foraging enrichments is to stimulate movement in the hope of improving skeletal and cardiovascular health, especially in broilers. Bailie et al. (2013) observed that commercial broilers provided with straw bales performed more walking and running and less sitting than birds in houses lacking bales, and this was associated with longer latencies to lie down suggestive of improved leg health. Increasing the density of straw bales from 1 bale/44 m^2 to 1 bale/29 m^2 floor space did not result in added welfare benefits (Bailie and O’Connell, 2014). The addition of bunches of string to windowed broiler houses provided with straw bales did not have clear effects on leg health but the strings were frequently pecked (Bailie and O’Connell, 2015) suggesting that this added opportunity for foraging behaviour was appreciated by the birds. Kells et al. (2001) observed higher locomotion in houses with than without straw bales at 1 bale/17 m^2 but no reduction in culling due to leg problems. Bizeray et al. (2002a,b) found no benefit of scattering whole wheat in the litter as it did not appear to be eaten, had no impact on time spent foraging or other measured activities and made no difference to production or health parameters relative to the control condition. Live mealworms were effective in stimulating broiler activity and ground pecking and scratching (Pichova et al., 2016). Although probably not practical to supply as an enrichment for broilers kept indoors, this finding points to the enrichment value of access to insects under free-range conditions.

8. Comfort behaviour enrichments

8.1. Dust bathing substrates

Dustbathing is a vigorous behaviour that involves loosening the substrate through pecking and scratching, and then squatting and using rapid vertical wing shakes to toss dusty substrate into the feathers. The bird then lies for a period, sometimes on one side with stretched legs, while stale, dirty feather lipids are absorbed into the dust. The dust bath ends when the bird stands up and shakes off the dust. Later, birds engage in preening to apply fresh waterproofing lipids from their oil gland to their feathers (van Liere, 1992). Dustbathing helps to maintain the integument in good condition by removing excess feather lipids (Olsson and Keeling, 2005), and it is considered as one of the behavioural responses evolved to maintain the insulative and waterproofing value of the feathers (van Liere, 1992) and, possibly, to control ectoparasites in wild birds (Clayton et al., 2010).

Dustbathing has been demonstrated to be an effective mechanism to control northern fowl mites (*Ornithonyssus sylviarum*) and body lice (*Menacanthus stramineus*) in laying hens when provided with dust boxes containing diatomaceous earth and kaolin (Martin and Mullens, 2012). These benefits were acquired only by the birds that did dustbathe in the dust boxes. Dust boxes containing sand alone were not effective in removing ectoparasites (Velozzi et al., 2015). Although ectoparasites are not a major health or performance issue in meat poultry because of their relatively short lifespan, infestations may be a bigger issue in breeding poultry.

Besides, with the exception of waterfowl, meat poultry species have a high motivation to perform dustbathing behaviour. When denied access to appropriate substrates, they may repeatedly start dustbathing sequences but be unable to complete the full sequence that would lead to a functional outcome (van Liere, 1992). Furthermore, they typically perform the behaviour at high levels when a suitable substrate is provided after a period of deprivation. These observations suggest that dustbathing behaviour is pleasurable (Widowski and Duncan, 2000) and that thwarting of access to dusty material is stressful (Vestergaard et al., 1997).

It is often assumed that, as most meat poultry are raised on litter, their motivation to dustbathe is satisfied. However, broilers (Shields et al., 2004, Toghyani et al., 2010, Villagrá et al., 2014) and other poultry (van Liere et al., 1990; Olsson and Keeling, 2005) have a strong preference to dustbathe in loose, fine-grained material such as sand and, especially, peat moss (Petherick and Duncan, 1989; Fig. 9). Such materials are preferred over the coarser materials that are most commonly provided as litter (e.g. wood shavings, rice hulls and chopped straw), which are not the best materials in which to perform dustbathing behaviour. Furthermore, the litter quality deteriorates over time, especially if environmental conditions are not well controlled, leading to caked litter that is unsuitable for dustbathing, sometimes very early on.

Figure 9. Broiler dustbathing in peat moss. Photo: R. C. Newberry.

Because access to a good dustbathing substrate is important for the welfare of poultry (Duncan et al., 1998), provision of sand or peat moss patches through the house should be an effective enrichment. Peat moss is, in fact, currently used as an enrichment in certain commercial broiler marketing schemes. Additionally, considering the relevance of dustbathing for maintaining optimal feathering, perhaps access to a high-quality dustbathing substrate would also carry some health and performance benefits. Some authors have hypothesised that, given the wide range of leg and wing movements performed during dustbathing bouts, stimulating dustbathing may be a potential avenue to increase exercise level and improve leg condition in meat poultry (Shields et al., 2004). Vestergaard and Sanotra (1999) were unable to determine if higher rates of dustbathing were protective against lameness in broilers but they did observe a negative association between lameness score and dustbathing frequency. Potential health and performance benefits from enrichment with attractive dustbathing materials have not yet been evaluated under commercial conditions for meat poultry, but possibly birds with longer production cycles would benefit the most.

8.2. Water baths

Whereas most meat poultry species use dust as their bathing substrate, waterfowl use water. Research on Pekin ducks showed that, when they were given access to water only from nipple drinkers or narrow-lipped bell drinkers, they were not always able to properly clean their eyes, nostrils and feathers (Jones et al., 2009; Driscoll and Broom, 2011). These results suggest that ducks need to be able to dip their head in water and splash water over their feathers to fully clean these areas. Access to water from showers, water baths and sufficiently wide troughs was effective in meeting these needs and in avoiding elevated water-directed behaviour towards a water bath at seven weeks of age as was observed in ducks reared with nipple drinkers only (Jones et al., 2009). On the other hand, Schenk et al. (2016) found that ducks had dirtier eyes, nostrils and feathers when reared with water troughs than nipple drinkers, along with lower feed intake, higher plasma corticosterone levels, higher mortality and more condemnations. Reasons for different results across studies are unresolved, although dirtiness of birds reared with nipple drinkers could result from insufficient water flow or nipple access (Schenk et al., 2016). It is clear that, when using open water sources, great care is needed to ensure that the water is clean and to avoid wet litter conditions that can have adverse effects on foot and leg health, and lead to elevated ammonia levels. Jones et al. (2009) observed that ducks spent more time near open water sources than nipple drinkers, which is important to note given the challenge of avoiding wet litter in these areas.

9. Enrichment and use of outdoor areas

Access to an outdoor area by commercial poultry is often perceived as a guarantee of animal welfare because of the wider possibilities for the birds to express natural behaviour including locomotory behaviour (Keppler and Folsch, 2000), foraging, playing and sunbathing (Fig. 10). In broilers, the extra space provided and the higher possibilities for exercise may have additional positive effects in regard to leg health (Fanatico et al., 2005), reduced risk of contact dermatitis and improved feather condition.

However, when access is voluntary, use of the outdoor area is often low and birds that do go outdoors show a strong tendency to remain within the immediate proximity of the house, presumably because the outdoor open area is somewhat intimidating for birds raised indoors. For commercial free-range broilers, Dawkins et al. (2003) reported a maximum of 15% of the flock using the range, and Rodriguez-Aurrekoetxea et al. (2014) indicated an average use of 5% in a slow-growing strain, with nearly 64% of the birds never observed outdoors. In adult laying hens, the frequency of use of the outdoor area is reported to range from 8 to 32% (Hegelund et al., 2005, 2006; Gilani et al., 2014; Rodriguez-Aurrekoetxea et al., 2016), with higher rates probably related to greater time to develop experience using the outdoor space as compared to meat poultry.

Many factors affect the use of the outdoor area in commercial free-range poultry, including climatic conditions (Hegelund et al., 2005; Richards et al., 2011, 2012), the size of the flock (Gebhardt-Henrich et al., 2014) and experience. Research in laying hens suggests that early experience in accessing the outdoor space is important for encouraging high use later on (Rodriguez-Aurrekoetxea and Estevez, 2016). Furthermore, this research indicated that individuals that used the outdoors more often had larger home ranges, moved further from the house, had better plumage condition and had a lower incidence of footpad dermatitis. Thus, early management of the birds in free-range systems to promote contact with the outdoors appears to be critical to ensure frequent and more uniform use of the outdoor area. Because the rearing periods for meat poultry are shorter, early management to promote outdoor use is especially relevant, as long as the climatic conditions are suitable considering the birds' age and feathering.

a) b) c)

Figure 10. Slow-growing broilers with outdoor access: a) exploring close to dense cover, b) play fighting and c) sunbathing. Photos: R. C. Newberry.

Rodriguez-Aurrekoetxea and Estevez (2014) and Fanatico et al. (2016) used environmental enrichments in an attempt to encourage early use of the outdoor area by slow-growing broilers. The enrichments, comprising perches (Fig. 11) and different forms of cover panels and shades, failed to attract more chickens to go outdoors in either study, but Fanatico et al. (2016) observed that chickens in enriched outdoor areas moved further away from the chicken house as compared to controls. When provided with a high number of protective wooden A-frames or short rotation coppice with willow, 35% and 43% of the flock, respectively, used the outdoor range (Stadig et al., 2016), suggesting that a high degree of protection is necessary in the outdoor area for the birds to make a good use of it. However, despite the relatively high use of the outdoor range, access to range was only moderately associated with reduced hock dermatitis and resistance to tonic immobility induction (an indicator of reduced fear), possibly because data were collated at the flock rather than individual level (Stadig et al., 2016). Given wide inter-individual variation in use of the outdoor areas, it would be desirable to assess health and welfare effects according to the duration of range use by individual birds.

The availability of a high degree of cover allows chickens the option to hide in the cover when perceiving a danger such as a potential predator (Zeltner and Hirt, 2006), rather than running inside the house, and can actually protect birds from being caught by predators. The degree of shelter from sun, rain and wind provided outdoors is also relevant. The shelter provided by trees planted within 20–25 m of the house was found to be effective in drawing laying hens outdoors (Bright et al., 2011).

a) b)

Figure 11. Slow-growing meat chickens in (a) standard outdoor area and (b) area enriched with perches. From A. Rodriguez-Aurrekoetxea (2016).

10.Discussion

10.1. Design considerations and constraints on enrichment

Although enrichments, by definition, have positive effects, details of their design and implementation are crucial to achieving the desired effects without unintended adverse side effects. For instance, indoor cover panels should be porous to avoid disrupting the ventilation but without holes so large that the birds could get their head or other body parts caught in them. They should be narrow to avoid serving as obstacles that could result in piling and short so that they do not disrupt the farmers' ability to check the condition of the flock. Evidence suggests that they should provide partial rather than solid visual cover, allowing for a 'Venetian blinds' effect, whereby the cover offers a sense of security through concealment while allowing birds to monitor events on the other side (Newberry and Shackleton, 1997). Furthermore, whereas vertical cover panels were effective in promoting vulnerable behaviours such as rest and preening, indicating their security-inducing effect, horizontal overhead panels of the same design did not have this effect (Newberry and Shackleton, 1987 and unpublished observations).

When considering perches, ramps and platforms, the design needs to take into account the large size and relative lack of agility of meat poultry birds. Unless well occupied, they may have negative effects by taking up floor space, thus effectively reducing the usable space per bird. The increased crowding could result in greater stress and reduced immunocompetence (Heckert et al., 2001). A challenge is deciding how much space to allocate to such structures given that, if birds are attracted to rest on them or around their base, their presence blocks access by other birds and may make it hard for birds located on top of them to get off without disturbing birds below. Well-used structures must be designed and located in a manner that does not lead to excessive accumulation of manure on top or underneath them, or manure raining upon birds below. The materials used in construction, and the profile, should allow birds to grip easily while also minimizing the risk of breast blisters (Nielsen, 2004) and bumblefoot, and avoiding the harbouring of mites. Ruiz-Feria et al. (2014) found that triangular ramps placed between feeders and drinkers reduced leg tendon breaking strength and growth rate of broilers reared to 49 days, suggesting that the design of those structures was difficult for heavy broilers to negotiate. The durability and ease of cleaning are also factors to consider when designing structural enrichments. The investment cost declines when items can be reused for many flocks but this advantage is lost if the labour cost to clean them is high.

When considering dustbathing and foraging materials, there can be concerns about the use of peat moss from the perspective of environmental sustainability. Sand is heavy to handle and abrasive on equipment. The use of straw, hay and other forages as enrichment can be constrained by concerns about biosecurity when bringing them into houses and by the potential for introducing unwanted seeds when used litter is spread on fields. Wood shavings bales may disintegrate within only a few days, limiting their durability as an enrichment. Because of their size, it would be challenging to bring in new ones once the birds are older and take up more floor space. Bale wrap can extend bale integrity but the plastic materials currently used are not environmentally sustainable. Care must be taken that materials are non-toxic and safe if ingested, will not cause gastrointestinal impaction and will biodegrade and not become pollutants in used litter.

When buildings incorporate windows to allow natural light, blinds that diffuse the light may be necessary to avoid panic reactions from lightning flashes or from patterns of moving light across the ceiling created by car lights on passing vehicles. Also, adjustments to the amount of light coming in through different windows may be needed if variation in lighting across the house leads to consistently higher densities in certain areas of the house. Diffuse light may also be needed to minimize the risk of feather pecking and cannibalism in flocks prone to such behaviour. Whereas dark brooders may be useful enrichments in houses where heating is supplied by brooders, they may not be effective in houses with underfloor heating where there is no incentive to seek brooder heat, considering that broilers do not appear to be particularly attracted to rest in dark enclosed spaces without supplementary heating (Newberry, personal observation).

There are multiple challenges to be considered when introducing access to the outdoors as an enrichment strategy (Newberry, 2017b). A well-drained substrate free of contaminants (e.g. dioxins and heavy metals) is essential. Birds should have clean feet when entering the house to avoid tracking in mud harbouring endoparasites. Although free-range broilers are attracted out of the house to drink from puddles and water troughs after rain showers (Jones et al., 2007), suggesting an enriching effect, open water that attracts wild waterfowl serves as a risk factor for the spread of avian influenza. Shade is necessary to avoid sun burn and birds must be protected from predators and from humans who may introduce garbage, inappropriate foodstuffs and even unwanted pet poultry. Finally, there can be challenges managing the diet when there is individual variation in consumption of forage, and crop impaction with fibrous vegetation can be a concern.

10.2. Future research

Many enrichment ideas presented in this chapter require further evaluation under commercial conditions. There is a need to determine optimum amounts of the different types of enrichment according to flock size and density, and to assess how different genetic lines and management conditions may affect results. Investigations should also evaluate how different forms of enrichment can be combined to maximize benefits towards different enrichment goals. When results are obtained across a representative number of flocks, it will be possible to evaluate how different enrichment programmes can be used to target problems detected based on flock culling and mortality data and on processing plant data such as incidence of footpad lesion scores and different reasons for condemnation and downgrading.

It is also clear that such research needs to be extended beyond broilers and broiler breeders to other meat poultry species such as turkeys and ducks, for which very limited data currently exist. Species- and age-appropriate enrichment strategies need to be developed taking into consideration the evolutionary background that has shaped the behavioural repertoire of each species. Such research will be useful when developing welfare assurance standards that currently incorporate vague enrichment requirements or incorporate a level of specificity that has not been established empirically (e.g. perch space standards for turkeys).

We have emphasized benefits that can be achieved through structural (e.g. perches, cover panels), spatial (e.g. access to free-range), foraging (e.g. straw bales) and bathing enrichments. Sensory enrichment is another enrichment concept that has received little attention to date, where the focus is on exposure to a variety of sights, sounds, smells, tastes and textures that stimulate different sensory modalities. Practical benefits could come from providing opportunities for voluntary exploration and habituation to a wide range of sensory stimuli, potentially reducing the risk of a panic reaction when unexpectedly encountering novel stimuli, such as during catching and transport. Cognitive enrichment is a related concept that is useful to consider when developing enrichment strategies, where the emphasis is on addressing opportunities for the birds to develop different skills that promote behavioural flexibility and stress resilience.

Research would also be warranted in the area of developing measures of quality of life that extend beyond reducing negative impacts on health into the realm of promoting positive psychological states such as pleasurable anticipation and joyfulness. The incorporation of enrichments into welfare assurance schemes is based on the perception that consumers are willing to pay more for products that contribute positively to the birds' quality of life. The science is lagging behind these marketing initiatives. There is a need for practical on-farm methods for quantifying positive aspects of quality of life that have a value beyond avoiding suffering.

Future lines of research should also place a high emphasis on considering the notion of enrichment while developing the basic housing elements. For example, platforms and perches can be designed to incorporate cooling and heating, enabling birds to select a comfortable microenvironment according to their individual needs. Automatic feeder lines could be designed in such a way that feed pans permit a larger number of birds to feed together, with the pipes in between feeders designed as perches, thus gaining added benefits from standard equipment. Enclosed verandas attached to houses could be used to offer varied sensory and cognitive enrichments while retaining a high degree of control over nutrition and biosecurity. Such developments could lead, eventually, to a future when the concept of enrichment is no longer relevant because enrichment has become standard, corresponding with a high level of sustainability from the combined perspectives of economic efficiency and social responsibility.

11. Conclusions

In this chapter, we have provided examples of how environmental enrichment can enhance the biological adaptation of poultry beyond the level obtained from providing basic resources such as feed and water. The main emphasis is to improve welfare by promoting species-typical behaviour, thereby reducing the risk of abnormal and damaging behaviours such as panic responses and feather pecking. Other potential benefits include safe, effective use of space and resources, increased ability to cope with change and promotion of positive psychological states.

Too often, enrichment is equated to the provision of a few simple 'toys' with no biological relevance to the birds. These toys may elicit a brief response to their novelty but are soon ignored. It is, thus, essential for a good enrichment programme to first determine the objectives of environmental intervention, then to design the required features of the enrichment to achieve the proposed goals, and finally to quantify and validate both positive and negative effects to assess overall net benefits. It is not sufficient simply to add an object and assume that it has an enriching effect; to categorize the modification as an enrichment requires documenting actual improvements in the welfare of the birds relative to results in its absence (Newberry, 1995). For enrichment programmes to produce a meaningful long-term benefit for the birds' welfare, they must have a sustained effect (e.g. through providing perches where birds can roost, straw bales that stimulate foraging and cover panels to reduce the sense of exposure). Thus, achievement of sustained beneficial effects can be seen as the key to sustainability in the development of effective environmental enrichment strategies.

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