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Environmental Enrichment/Improvement: Effect on Performance of Commercial Broiler Strains

ABSTRACT

This work reviews the effect of environmental enrichments (perches, platforms, stocking density, outdoor access, bale, and dust bathing substrates) on the performance of fast and slow-growing commercial broiler strains. The performance of both slow and fast-growing commercial broiler strains under conventional production systems are generally poor, especially regarding the welfare status. One of the strategies to improve the performance of commercial broiler strains is by adding enrichment objects to production systems. The addition of enrichments to production systems should improve animal welfare, have no negative effect on production performance, and be both economically practicable and feasible to employ. Perches and platforms are the most common enrichments used to increase the activity of broiler chickens to improve leg conditions. The use of perches and platforms could lead to the reduction in the incidence of footpad dermatitis, hockburns and breast blisters, with subsequent effects on meat quality. Moreover, the provision of outdoor access could improve the biology responses of broiler chickens to various environmental stimuli, with a profound effect on performance and meat quality traits. Furthermore, another enrichment strategies that could increase the exploratory behavior and the general welfare of broiler chickens is the use of dustbathing and bale substrates. Moreover, adjusting the stocking density provides broiler chickens with the necessary space for movement, reduces crowding, trampling and the associated agonistic behavior. However, the effect of some of these enrichments (perches, platform, bale) objects may vary depending on height, age, sex, and strain of the chickens.

INTRODUCTION

Poultry production, especially of broiler chickens, has seen substantial growth and increased interest, making the broiler industry one of the fastest growing industries among the livestock sectors. The genetic selection and improvement for faster growth and higher breast muscle production to meet the constant global demand and supply of chicken meat has led to several welfare problems, such as a reduction in the activeness of broiler chickens coupled with skeletal problems such as tibial dyschondroplasia. Tibial dyschondroplasia (TD) is an intractable tibiotarsal bone disorder in fast-growing poultry, particularly broilers and turkeys, resulting in chondrocyte death of the tibiotarsal growth plate due to insufficient or untimely blood supply (Huang *et al.*, 2019). This has decreased the ability of modern-day commercial broiler strains to exhibit certain ancestral natural behaviors such as perching due to their heavy body weight and lack of adequate support for it. Moreover, faster muscle production causes larger muscle cells, limiting spaces



between muscle fibre and oxygen supply to muscle cells, resulting in cell death and leading to conditions known as wooden breast. Furthermore, it has been reported that in many parts of the world, commercial broiler chickens are reared with high stocking densities, both in production systems with little space per chicken and in those lacking in environmental enrichments that allow the exhibition of natural behaviors, which could lead to stress and increase agonistic behaviors. According to Bessei (2006), broiler chickens are mostly reared in barren environments at high stocking densities, and lameness, hock burns, breast blisters, and footpad dermatitis have been reported to be some of the major welfare-related issues in modern-day broiler chickens (Bradshaw *et al.*, 2002; EFSA, 2010; Bessei, 2006). These welfare-related issues are caused by the frequent contact and pressure of the skin of the breast, hocks, and feet against humid and soiled litter materials (Ekstrand *et al.*, 1997, 1998). In a study conducted by de Haas *et al.* (2014a), they observed that chickens housed in a large group (stocking density) were associated with a high prevalence of severe damage, the severity of which was higher in chickens housed in the floor system than those housed in the aviary system. The authors further reported that an adjusted management system reduced feather damage compared to the standard management system. High stocking density coupled with poor welfare has been reported to also be a major limitation to behavioral expression (EFSA, 2010). The rearing or production of fast-growing broiler strains are more commonly practiced using indoor-production systems, and welfare-related issues have been reported to be more profound in fast-growing broiler strains than in slow-growing ones. On the other hand, slow-growing broiler strains are reared in organic production systems or free-range systems, and although these broiler chickens are more active and are also provided with richer environments than fast-growing strains, it has been reported that slow-growing strains may also suffer welfare-related issues such as lameness, breast blisters, and contact dermatitis (Van de Weerd *et al.*, 2009).

Environmental enrichment has been defined by several authors as the inclusion of a biologically important feature in the surrounding of an animal to aid, motivate, and create several platforms for the exhibition of natural behavior (Newberry & Estevez, 1997; Newberry, 1999; Mellen & MacPhee, 2001); however, Van de Weerd & Day (2009) further redefined the definition of environmental enrichment by adding

several aspects such as animal health, practicality, and economics of the production system. The authors argued that a successful enrichment strategy should increase species-specific behavior, enhance animal health and the economics of the production system, as well as be feasible to employ. Therefore, any enrichment strategy that hinders animal health as well as having too many economic constraints should never be implemented.

The manipulation of the environment of the production system or the provision of a more stimulating environment has been predicted to improve welfare in both fast and slow-growing broiler chickens (Kells *et al.*, 2001; Bessei, 2006; Bailie *et al.*, 2013). Moreover, it has been reported that the movement of animals can be influenced by environmental enrichment (Leone *et al.*, 2007), thereby enhancing the adequate use of space (Newberry & Shackleton, 1997; Cornetto & Estevez, 2001a). Similarly, other authors have reported that environmental enrichment ensures the even distribution of animals (Cornetto & Estevez, 2001b), reduces aggressive behaviors (Cornetto *et al.*, 2002), and fear and stress (Grigor *et al.*, 1995; Bizeray *et al.*, 2002b; Ohara *et al.*, 2015). Riber *et al.* (2018) also reported that the addition of enrichment to the rearing environment promotes better use of the environment and increases the ability of the animals to cope with behavioral and physiological challenges. For example, it was reported that enrichment leads to the reduction of fear in broiler chickens, especially if it provides them with shelter or the possibility of temporarily escaping the floor surface (Brake *et al.*, 1994; Jones, 1996; Cornetto & Estevez, 2001a;). Vas *et al.* (2023) reported that an increased diversity of environmental enrichment types in commercial broiler production systems was associated with higher expression of behavioral indicators of positive affect, including social play, curiosity-driven inquisitive exploration, and comfort behavior. Ohara *et al.* (2015) also reported that broiler chickens in enriched production systems invested more time in stand-resting and locomotion and less time in feeding, drinking, and sit-resting compared to their counterparts in conventional production systems. Although enrichment of the production system have been reported to have a positive influence on production and welfare traits, Güz *et al.* (2021) reported significantly lower body weight and poorer feed conversion ratio (0-35d) in chickens reared in enriched production systems than in those housed in conventional production systems. Other authors have also reported no significant effects of pen enrichments



on plumage cleanliness, leg deformities, or body weight of broiler chickens (Tahamtani *et al.*, 2020). However, de Haas *et al.* (2014b) observed that the disruption and limitation of litter supply as an enrichment at an early age on the rearing farms increased severe feather pecking, feather damage, and fear.

Therefore, this work aimed at reviewing the influence of environmental enrichments (perches, platforms, outdoor access bales, stocking density, and dustbathing substrates) on the performance of commercial broiler strains.

The use of Perches and Platforms in Commercial Broiler Production

The ancestor of the modern-day domesticated chicken, the red jungle fowl, rested on trees or perches, and this behavior has been passed down to their present-day relatives (Sandilands *et al.*, 2009). Furthermore, the red jungle fowls also perched on trees to escape predators or aggressive/dominant individuals. Due to these reasons, one of the effective enrichment strategies is to provide commercial broiler strains with perches. The use of perches influences production, welfare and behavioral traits; and perches made from different materials with different designs are used in various commercial broiler productions. Traditionally, these consist of suspended bars either made of plastic or wood-structures, similar to the ones provided for laying hens. Different studies using fast-growing genotypes have shown that the use of perches in these strains varies from <2% during the time of the behavioral observation to an average of 25% during the day time (LeVan *et al.*, 2000; Su *et al.*, 2000; Pettit-Riley & Estevez, 2001; Ventura *et al.*, 2012; Groves & Muir, 2013). This low use of perches among fast-growing genotypes could be attributed to body weight, coupled with skeletal problems such as tibia dyschondroplasia, as well as a poor perch designs. Slow-growing strains, on the other hand, have lower body weight compared to fast-growing strains, with better bone strength that makes them better and more efficient perch users than fast-growing genotypes. For example, in a comparative study conducted by Bokkers & Koene (2003), they observed that perching was more common (34.3% and 10.1% respectively) among slow-growing strains (JA 657) than fast-growing strains (HI-Y from the breeding company Hubbard) during the day time. Other authors (Yngvesson *et al.*, 2016) have reported that, under organic production, slow-growing strains (Rowan Ranger and Hubbard CYJA57) perched two times more than their fast-growing counterparts

(Ross 308). Lewis *et al.* (1997) also reported that ISA broiler chickens were much more active and made greater use of perches; however, Ross broilers generally made very little use of the perches, especially those that were 580 and 1050 mm above the ground level.

Riber *et al.* (2018) stated that perches serve as a means to get away from heat emerging from heated surfaces or litter materials. Estevez *et al.* (2002) tested the effect of two metal perches containing water either at 10°C or 30-34°C, and reported that broiler chickens preferred cooled perches over non-cooled perches, with the most cooled part of the cooling-perches being preferred. Zhao *et al.* (2013) also observed a decreased number of hock burns, footpad dermatitis, and cleaner plumage in Arbor Acres broilers provided with cool perches. Other authors have also reported that aggression and disturbances such as pushing and trampling among flocks could be reduced with access to perches (Ventura *et al.* 2012). Furthermore, it has been reported that the bone development of broiler chickens can be improved by increasing activity during the early growing period (Reiter & Bessei, 1998, 2009; Bizeray *et al.*, 2002a), and this may have a profound effect on lameness. The use of perches could serve as a potential strategy to motivate broiler chickens to increase behavioral activities related to perching (descend and ascend), which could improve bone strength in commercial broiler strains. In fact, other studies (Bench *et al.*, 2016; Türkyilmaz *et al.*, 2020) have observed higher bone density and area, as well as superior tibia traits (weight, diameter, length, robusticity index, and weight-length index) in broiler chickens housed with perches, as compared to those reared without perches. However, some authors have reported that the provision of perches did not affect either lameness score, tibia dyschondroplasia, or tibia curvature in fast-growing broiler strains (Su *et al.*, 2000; Bailie & O'Connell, 2015).

The availability of perches in production systems has been reported to influence production, and carcass and meat quality traits. For instance, Zhao *et al.* (2013) reported that the use of cool perches increased body weight gain and feed conversion efficiency of broilers. However, the authors did not observe any significant difference in terms of the weight of the breast muscle, thigh muscle, heart, and liver. Moreover, the drip and cooking loss of the pectoral major and biceps femoris were both lower in the group with cool perches. The authors explained that decreased drip and cooking losses found in broilers with cool perches indicate a beneficial influence on meat quality, presumably



due to improved thermolysis from the greater use of perch. Estevez *et al.* (2002) also reported the highest eviscerated weight in female broiler chickens with access to cool perches, suggesting that this could be related to the higher perching behavior observed in this group. Nevertheless, the authors did not find any significant difference in mean body weight between the experimental groups. Contrarily, Akşit *et al.* (2017) reported a higher body weight during the second and third week of the rearing phase in broiler chickens reared without perches than in those reared with perches. The authors further reported that broiler chickens without access to perches had the best feed conversion efficiency between 0-21d of the experiment. Nevertheless, no significant effect was observed on feed intake between broiler chickens reared with or without perches. Similar to what was reported by Akşit *et al.* (2017), a different study conducted by Martrenchar *et al.* (2000) also revealed that male broiler chickens reared at a stocking density of 22 broiler chickens/m² without perches had slightly higher body weight than their counterparts reared at the same stocking density with perches. However, feed conversion and carcass lesions were independent of the presence of perches. Other studies have reported no significant effect of perch treatments on growth and carcass characteristics. For example, Bailie & O'Connell (2015) reported that the provision of perches did not influence the slaughter weight of broiler chickens, and Nielsen (2004) also reported that the availability of perches did not have any significant effect on growth weight, daily feed intake, and eviscerated weight. Pettit-Riley & Estevez (2001) reported no effect of perch-treatments on final body weight and feed conversion, and the authors further argued that mortality not caused by heat stress was not influenced by the perch treatments.

Although perches have been proven to improve performance, the effective use of perches may vary depending on the angle and height of perch, and the sex, age of the chicken (LeVan *et al.*, 2000; Pettit-Riley & Estevez 2001; Estevez *et al.*, 2002; Nielsen, 2004; Bailie & O'Connell, 2015; Ohara *et al.*, 2015; Norring *et al.*, 2016; Türkyılmaz *et al.*, 2020) and strain, and this may explain the reasons for differences in results reported by the various authors.

The use of platforms has been described as a different approach for providing broiler chickens with different elevated options. In a study conducted by Bailie & O'Connell (2016), they observed that fast-growing broiler strains preferred raised platforms

to traditional perches. Moreover, Bach *et al.* (2019) observed a higher usage of platforms for resting, standing, and performing locomotive behaviors than any of the other types of enrichments. Lourenço da Silva *et al.* (2023) also reported that the use of step platforms did not influence exploratory behavior; however, the prevalence of subclinical spondylolisthesis was lower in the group with step platforms compared to the group provided with hay bales. It has also been reported that elevated platforms reduced fear in broiler chickens (Tahamtani *et al.*, 2018). Furthermore, Tahamtani *et al.* (2020) observed that broiler chickens housed with access to a 30 cm elevated platform had healthier footpads compared to broiler chickens housed with access to straw bales. Some authors also reported better leg health in broiler chickens with access to platforms, as this resulted in significantly lower mean gait scores, and a lower percentage of tibial dyschondroplasia (Kaukonen *et al.*, 2016). Moreover, other factors such as the age, sex, and strain of chicken, the height and platform type could either limit or enhance the effective use of platforms, which may account for the differences in results observed in the various studies.

In summary, when managed properly, the provision of perches and platforms could help encourage the expression of specific behaviors among broiler chickens and also beneficial for the improvement of welfare, growth, carcass, and meat quality characteristics of both slow- and fast-growing-broiler strains.

The Influence of Stocking Density on Performance

The improvement of the environment through the provision of adequate space per bird is one of the major ways to enhance the production, meat quality, and welfare performance of commercial broiler chickens. Adequate space is very important to aid movement, reduce aggressive behaviors, and promote proper air circulation within the flock. However, conventional broiler production involves the housing of broiler chickens in floor systems with high stocking densities. Stocking density has also been observed to influence litter quality, such as its moisture retention capacity. In general, increasing the number of broiler chickens per unit of area has been confirmed to depress production traits and welfare scores. High stocking densities does not only influence growth performance, but also alters the behavior, carcass, and meat quality characteristics of broiler chickens. Tsiouris *et al.* (2015) concluded that stocking density could affect the viscosity of intestinal



contents and the prevalence of necrotic enteritis in chickens.

For instance, Zhao *et al.* (2013) compared the performance of broiler chickens under 3 different stocking densities (12, 16, or 20 broiler chickens/ m^2), observing that a high stocking density (20 broiler chickens/ m^2) decreased the growth and welfare of broiler chickens. However, none of the stocking densities had any significant effect on carcass composition or meat quality traits. Moreover, Simitzis *et al.* (2012) observed lower final body weight, feed intake, and locomotion, but a higher physiological and oxidative stress indicator among broiler chickens under a high stocking density (13 broiler chickens/ m^2). Nevertheless, the authors observed no significant effect of the stocking densities on muscle color traits, pH_{24} , cooking loss, and shear values. Furthermore, Thomas *et al.* (2004) reported that broiler chickens reared at a lower stocking density (5 broiler chickens/ m^2) had the highest feed consumption compared to the other groups (10, 15, and 20 broiler chickens per m^2), but no breast lesions were observed in the carcasses of any of the groups. The authors argued that none of stocking densities influenced feed conversion efficiency, mortality, or carcass traits. Kryeziu *et al.* (2018) also observed that broiler chickens reared under a lower stocking density (14 broiler chickens m^{-2}) had a higher body weight than those reared under medium or high stocking densities (18 broiler chickens m^{-2} and 22 broiler chickens m^{-2}). The authors further reported higher feed consumption and better feed conversion efficiency in the group with lower stocking density, despite it not being statistically different from the other groups. Lewis *et al.* (1997) observed that broiler chickens reared at 17.0/ m^2 had lower feed intake and lower body weight gain than their counterparts reared at a stocking density of 4.25/ m^2 . Additionally, Farmer *et al.* (1997) have studied the meat quality traits of broiler chickens reared under different stocking densities (high, 17.0/ m^2 and low, 4.25/ m^2). The authors reported that although the stocking density had no significant effect on the texture of the breast or the thigh meat, there was a tendency for breast meat from broiler chickens reared at the low stocking density to be tougher and more resistant to the knife than the meat of high stocking density broiler chickens. The authors explained that the high activity among broiler chickens reared with low stocking density might have influenced the toughness of their meat. In the same study, meat from broiler chickens reared at the low stocking density showed an increase in odour and flavor intensity

compared with the meat from high stocking density broiler chickens. These changes in flavor and odour may be caused by significant changes in the fatty acid composition of the muscle, which again suggests that the level of activity of the broiler chickens might have affected muscle metabolism. It may also be possible that the additional exercise of the broiler chickens at a lower stocking density favored the production of muscle components important for the formation of odor and flavor compounds. Moreover, other authors also observed that broiler chickens reared at 10 broiler chickens/ m^2 had higher body weight at 6 weeks of age compared to the other groups (13 broiler chickens/ m^2 and 16 broiler chickens/ m^2); however, at 3 weeks of age, none of the stocking densities had any significant effect on body weight (Škrbić *et al.*, 2009). However, Sekeroglu *et al.* (2011) reported that stocking density (9, 13, and 17 broiler chickens m^{-2}) had no significant effect on carcass yield, meat pH, color, and internal organ weights.

Puron *et al.* (1995) observed the effect of different stocking densities on the performance of male and female broiler chickens. The authors found that the highest stocking density of 18 males/ m^2 resulted in a 3% decrease in body weight compared with the lowest density of 10 males/ m^2 at 7 weeks of age. For the females, the difference between the highest (20 broiler chickens/ m^2) and lowest stocking densities (11 broiler chickens/ m^2) was only 1.5%. The decline in feed intake at the highest stocking density compared to the lowest stocking density was 3.7% and 3.9% for males and females, respectively. Although none of the stocking densities had any effect on feed conversion ratio or mortality, the authors reported that the kg of broiler/ m^2 and profit margins increased with stocking broiler chickens up to 17 males/ m^2 and 19 females/ m^2 . Male broiler chickens have faster metabolic and growth rates, leading to a higher production of metabolic energy. It is therefore speculated that the higher metabolic energy produced by the male chickens, coupled with environmental stress and other discomfort associated with high stocking density, might have had a more profound negative effect on male broiler chickens than females.

Gholami *et al.* (2020) also observed the influence of different stocking densities in different climates on the performance and economic returns of broiler chickens. The authors reported no significant effect of the stocking densities on growth parameters during the starter phase, but the group reared with 10 broiler chickens/ m^2 had the best body weight gain and feed



conversion ratio during the growing phase, and broiler chickens stocked at a density of 17 chicks/m² had the best economic benefits in hot and dry climates.

Additionally, while no effect of stocking densities (30-32 kg per m², 36-38 kg and 42-44 kg per m²) on tonic immobility, pecking, resting, locomotion, and standing behaviors were observed by Son (2013), other authors (Uzum & Toplu, 2013) observed a higher duration of tonic immobility among broiler chickens reared under high stocking density (18 broiler chickens/m²). Andrews *et al.* (1997) also observed that chickens housed at a lower stocking density (1.7 kg/m²) spent more time walking and sitting, and less time dozing and sleeping, pecked more at inanimate objects, and interacted more with other broiler chickens. Moreover, the authors reported that broiler chickens stocked at a high density (14 kg/m²) early in the rearing period were most active in the presence of people. In another experiment by Pettit-Riley *et al.* (2002), broiler chickens were reared at three crowding levels: least crowded (0.1 m² per broiler chickens), moderately crowded (0.067 m² per broiler chickens), and highly crowded (0.05 m² per broiler chickens), corresponding to group sizes of 45, 67 and 90 broiler chickens, respectively. The authors confirmed that levels of threats and other types of aggressive interactions per broiler chicken were significantly lower in the moderately crowded treatment compared to the least crowded treatment. Furthermore, Thomas *et al.* (2004) observed the behavioral expression of broiler chickens at 3 different stocking densities (very low, low, medium, and high). The authors showed that, at 5 weeks of age, lying behaviour was significantly lower in the low, medium, and high stocking density group compared to those reared with a very low stocking density. However, standing and walking behaviors were lower in the group housed with a very low stocking density compared to the other groups. The authors speculated that increased stocking density resulted in decreased opportunities for undisturbed resting behavior. In the same study, foraging behavior was higher in the group reared with very low density, but dustbathing, preening, eating, or drinking behaviors were not influenced by stocking density.

Furthermore, Sanchez-Casanova *et al.* (2019) have confirmed higher feeding, locomotion, and preening behaviors, but lower lying behavior among broiler chickens housed with low stocking density (5 broiler chickens/m²) compared to their counterparts housed with high stocking density (10 broiler chickens/m²). It is therefore speculated that higher stocking densities may

hinder movements within the flock, leading to severe pushing and trampling, which could cause several physical damages and physiological changes affecting the overall performance of broiler chickens. Moreover, the reduction in locomotion and higher percentage of lying behavior among broiler chickens reared with high stocking density may further increase the duration of contact of the hock, foot, and breast with the litter materials, increasing the likelihood of prevalence of breast blisters, footpad dermatitis, and hock burns. In fact, higher gait score, footpad and plumage scores, litter moisture, and leg problems have been observed under high stocking densities (Hall, 2001; Thomas *et al.*, 2004; Son, 2013).

Additionally, Qaid *et al.* (2016) observed that high stocking density (120 broiler chickens/m²) increased heterophil/lymphocyte ratio and plasma cholesterol, as well as decreased the weight of liver and lymphoid organs. Beloor *et al.* (2010) also observed the expression of heat shock proteins (HSP 70 and HSP 90) under high (0.0578 m² /broiler chickens), standard (0.077 m² /broiler chickens), and low (0.116 m² /broiler chickens) stocking densities. The authors reported that while the expression of HSP70 was significantly higher in the high-density group compared with the other groups, it did not differ between the low and standard-density groups. Moreover, the stocking density did not have any significant influence on the expression of HSP90. HSP90 and HSP70 are indicators of stress and the higher levels in the high-density group indicate a high level of stress among broiler chickens in that group. According to Li *et al.* (2019), high stocking density (18 broiler chickens/m²) led to decreased bursa weight and immunoglobins (IgG and IgA) concentrations in broiler chickens. Nasr *et al.* (2021) also observed the influence of different stocking densities (14 broiler chickens/m², 18 broiler chickens/m², and 20 broiler chickens/m²) in two strains of broiler chickens (Arbor Acres broiler and Ross-308). The authors reported higher concentrations of blood triglyceride, and cholesterol, but lower concentrations of high-density lipoprotein (HDL), immunoglobulin G, and total antioxidant capacity in the high-density (20 broiler chickens/m²) groups of both strains. In the same study, the heterophil/lymphocyte ratio, as well as the blood concentrations of creatinine, urea, alanine aminotransferase, and aspartate aminotransferase, were highest in the high density (20 broiler chickens/m²) group, while the concentrations of total blood protein, albumin, and globulin were the lowest in this group. Similarly, Uzum & Toplu (2013) also observed a higher heterophil/lymphocyte ratio in



broiler chickens reared under high stocking density (18 broiler chickens/m²). It is therefore speculated that the lower weight of lymphoid organs as well as the lower concentrations of immunoglobins at higher stocking densities are indicators of reduced immuno-response in broiler chickens. Also, the higher concentrations of blood triglyceride and cholesterol are indicators of higher stress levels in broiler chickens reared under high stocking density. Moreover, Alanin aminotransferase and aspartate aminotransferase are enzymes secreted by the liver, and their higher concentrations in the blood may indicate damage to liver or liver malfunction. A higher heterophil/lymphocyte ratio has been reported to be an indicator of stress, which is negatively correlated with the immune performance of broiler chickens. However, Tuerkyilmaz (2008) has confirmed no significant effect of stocking densities (15, 20, and 25 broiler chickens/m²) on heterophil/lymphocyte ratio, corticosterone concentration, and immune response.

In summary, higher stocking densities may influence several behavioral, clinical, and physiological changes in broiler chickens, which may lead to poor production, meat quality, and carcass traits, as well as reductions in welfare status.

The Influence of Outdoor Access on Performance

Conventional broiler chickens are reared with no outdoor access, while broiler chickens under organic production or free-range systems are given access to outdoor ranging areas. The provision of outdoor access has been reported to influence behavior, welfare and growth performance, and carcass and meat quality characteristics of broiler chickens.

Husak *et al.* (2008) reported that free-range systems or rearing systems with outdoor access are perceived as being natural, environmental and animal welfare friendly. Compared with the conventional confined system, outdoor systems can decrease stress conditions and increase broiler chickens comfort (Blokhuys *et al.*, 2000), leading to stronger leg bones and walking abilities (Fanatico *et al.*, 2005a, 2008). Moreover, a great number of researchers have found that outdoor access could improve the quality and flavor of meat products in comparison with conventional confined systems (Fanatico *et al.*, 2005b; Wang *et al.*, 2009). Fanatico *et al.* (2008) observed the performance of fast- and slow-growing genotypes with or without outdoor access. The authors reported that while outdoor access did not have any significant effect on body weight gain, breast weight, breast yield, carcass weight, and

bone mineral density, feed intake was higher in broiler chickens with outdoor access. However, mortality and feed conversion efficiency were worse in this group. Again, Fanatico *et al.* (2006) compared the influence of outdoor access on the performance of slow, medium, and fast-growing broiler strains. The authors reported higher breast weight in the strains with outdoor access compared to their counterparts without outdoor access, but outdoor access had no significant effect on meat flavor. Mikulski *et al.* (2011) also reported no significant differences in the body weight, feed conversion efficiency, mortality, breast muscle, thigh muscle, drumstick, and abdominal fat weight of slow and fast-growing broiler strains housed with or without outdoor access. The authors observed that the breast muscle of broiler chickens with outdoor access had the highest protein content but the lowest water-holding capacity and lightness (L) values. Furthermore, the thigh muscles of broiler chickens with outdoor access had the lowest lightness (L) and yellowness (b) values compared to those reared without outdoor access. In the same study, while the production system did not affect meat aroma, flavor, breast meat fatty acid profile, tenderness, or shear force, the meat from broiler chickens housed indoors was more juicy than those with outdoor access. It is therefore speculated that increased activity among chickens with outdoor access might have interfered with the compounds or the formation of compounds that influence tenderness or juiciness of meat. Moreover, it is also speculated that the higher activity among broiler chickens with outdoor access might have increased the energy requirement for movement, leading to further breakdown or use of the fat reserve in the body or muscle, causing a reduction in fat levels in meat (intramuscular fat) of chickens with outdoor access compared to those with limited spaces for movement. This reduction in intramuscular fat content could influence the meat aroma or juiciness, since the fat content of meat has a profound effect on these traits. Other authors (Raach-Moujahed & Haddad, 2013) have also reported that Arbor Acres broiler chickens with outdoor access had higher body weight, body weight gain, and feed intake, a better feed conversion ratio, and a lower mortality compared to Tunisian local breeds with outdoor access. The authors further reported that slaughter weight, carcass traits (eviscerated carcass, carcass yield, abdominal fat, thigh, and breast) and the weight of digestive organs (gizzard fat, gizzard, heart, liver) were all heavier in the Arbor Acres breeds with outdoor access compared to the local chickens.



Additionally, Fanatico *et al.* (2007) identified that the fat, vitamin, and ash contents of the breast meat of fast- and slow-growing broiler strains with outdoor access did not differ compared to their respective counterparts housed indoors. However, both strains with outdoor access had higher breast muscle protein contents than their counterparts reared indoors. The authors also reported that while the lightness (L^*) of the breast meat was higher in slow-growing strains housed indoors, the lightness (L^*) of the breast meat for fast-growing strains with outdoor access was higher than their counterparts kept indoors. The redness (a^*) of the breast meat was not significantly different for either of the strains housed indoors compared to their counterparts with outdoor access. However, the yellowness (b^*) of the breast meat was significantly higher among slow-growing strains with outdoor access compared to their counterparts housed indoors. The authors further argued that the production system had no significant effect on breast weight, drip, and thaw loss, but cooking loss was significantly lower in broiler chickens with outdoor access compared to their counterparts reared indoors.

Also, Chen *et al.* (2013) reported that outdoor access did not affect growth performance, carcass yield, meat yield, muscle protein content, muscle fiber characteristics, or the water holding capacity of meat, but the provision of outdoor access increased the shear force of the breast meat as well as decreased the fat contents of the thigh muscle. The authors further argued that broiler chickens with outdoor access from 35 days of age also had lower fat content in their thigh muscles than those with outdoor access from 70 days of age. It is therefore speculated that the higher exercises may lead to rapid contraction and expansion of the breast or thigh muscle, causing it to be strong and resistant to knives. However, this constant expansion and contraction of the muscle could also enhance the diameter and length of the muscle fibers, leading to a larger muscle size. For instance, Jiang *et al.* (2011) reported a significantly lower muscle fiber diameter but a greater muscle fiber density among free-range broiler chickens. Moreover, the free-range broiler chickens had significantly lower abdominal fat percentage, meat shear force, drip loss, and breast meat color (b^*) value, but a significantly higher pH value compared with the control. Furthermore, the cholesterol, lactic acid, glycogen, and malondialdehyde of breast muscle were significantly lower in the free-range broiler chickens than in the control. Moyle *et al.* (2014) also observed the performance of fast-growing broiler strains reared

with or without outdoor access in different seasons of the year (spring, fall, and summer), reporting no significant effect of the production systems on body weight, feed conversion ratio, and bone strength in any season.

Sanchez-Casanova *et al.* (2021) also reported that the provision of outdoor access had no significant effect on body weight, body weight gain, and feed conversion ratio. However, carcass yield was higher in broiler chickens with outdoor access. Moreover, the broilers housed with low stocking density (5 broiler chickens/m²) coupled with the provision of outdoor access had the best feed conversion ratio than the rest of the group. Other authors (Połtowicz & Doktor, 2011) also identified that while higher body weight and lower mortality were recorded among broilers housed indoors compared to those with outdoor access, the production system had no effect on dressing percentage, carcass color, and most of the carcass quality parameters. Nevertheless, free-range male chickens had higher carcass weight loss than their female counterparts. In the same study, the authors observed that the production system did not have any significant effect on the majority of the breast muscle (color, water holding capacity, drip loss, thermal loss, shear force) and thigh muscle traits (color, water holding capacity, shear force).

Cygan-Szczegielniak & Joanna Bogucka (2021) also observed the performance of male and female broiler chickens reared under an organic system. The authors reported that under the same production system, males had higher body weight, daily weight gain, carcass weight, and carcass yield than females, but the pectoral muscle did not differ between males and females. Furthermore, pectoral muscle pH, color, water holding capacity, shear force, fiber diameter, dry matter, protein, fat, total and soluble collagen of both sexes under organic production did not differ significantly from one another. Additionally, de Almeida & Zuber (2010) also did not observe any significant difference in terms of carcass yield, and wings, legs, breast, abdominal and skin fats of broiler chickens reared either indoors or with outdoor access. However, Cygan-Szczegielniak *et al.* (2019) also reported that compared with a semi-intensive system, broiler chickens reared without outdoor access (intensive system) had higher body weight, daily weight gain, and yield of pectoral muscle; however, those with outdoor access (semi-intensive system) had significantly higher carcass weight and carcass yield. Moreover, in comparison with those reared indoors, those with outdoor access



exhibited a lower breast meat pH, shear force, and pectoral muscle fiber diameter, but had higher lightness (L^*) and yellowness (b^*) values. Furthermore, the pectoral muscle of the broiler chickens reared indoors had higher dry matter, protein, and fat content than that of those with outdoor access. Li *et al.* (2017) also observed the performance of broiler chickens reared in cages, litter, and free-range production systems. The authors observed lower feed intake, final body weight, and body weight gain, and poorer feed conversion ratio in the free-range broiler chickens compared to the other groups (cage and floor system). The free-range chickens had higher carcass and breast muscle weight than those in cages, but lower values than those in the floor system. Also, the abdominal fat content was lower in the free-range chickens than in the rest of the group. The authors argued that the production system did not have any significant effect on meat pH, water holding capacity, intramuscular fat content, and inosine monophosphate, but shear force among the free-range broiler chickens was lower than those reared in the floor system but higher than those in cages. Similarly, Sekeroglu *et al.* (2009) have reported a lower body weight and total feed intake among free-range broiler chickens compared to those housed in the floor system. However, feed conversion ratio, heart, liver, spleen, and abdominal fat was not influenced by the production systems. The authors reported that while the fatty acid composition of the breast meat did not differ between the two production systems, the breast meat of the free-range chickens had the lowest redness (a^*) value, as well as the highest yellowness (b^*) value.

Another research by Sanchez-Casanova *et al.* (2019) revealed that broiler chickens with outdoor access had higher locomotion and foraging behaviors than their counterparts reared without outdoor access. However, preening, feeding, drinking, lying, standing, and dustbathing behaviors did not differ between the production systems. While the broiler chickens with outdoor access had lower heterophil/lymphocyte ratios and higher lymphocyte counts, the levels of corticosterone and heterophils did not differ between the production systems. Moreover, body weight at 3 and 6 weeks of age, as well as the spleen and bursa weight, were heavier in the broiler chickens reared indoors compared to those with outdoor access. Zhao *et al.* (2014) confirmed that broiler chickens with outdoor access had significantly higher standing, walking, exploratory, dust-bathing, and preening behaviors than those housed indoors. However, the

production system did not have any significant effect on feeding, drinking, and fighting behaviors. The authors further reported that the fluctuating asymmetry of the tibia length of the broilers with outdoor access was significantly lower than that of those housed indoors, while no significant difference was found for the fluctuating asymmetry of the tibia diameter and wing length. While the production system had no significant effect on meat quality traits, the broiler chickens reared with outdoor access had higher mortality and duration of tonic immobility than those housed indoors.

In summary, the provision of outdoor access is more likely to increase locomotion, leading to improvement of leg problem; exposes broiler chickens to various environmental challenges, leading to a reduction of stress and fear; while also providing adequate space for the exhibition of natural behaviors. Although some authors have reported that increased activity may be responsible for the variations in meat quality, the scientific explanation on how excessive locomotion may affect muscle metabolism and meat fatty acid profile, as well as the effect locomotion has on compounds that affect meat colorisation is yet to be studied, making it an important area for future research. However, broiler chickens with outdoor access are more likely to forage on a wider range of insects and pasture plants. Insects are rich sources of minerals such as calcium, which plays a vital role in bone mineralization. Pasture plants are also important sources of fatty acids, carotenoids, and antioxidant agents that may help improve meat quality.

Although the provision of outdoor access is associated with better welfare, the high consumption rate of outdoor plants has also been associated with a negative impact on performance traits, since the digestive systems of chickens is not capable of synthesizing the high amount of cellulose present in forage plants. This could have been the reason for the difference in results related to performance traits of broiler with outdoor access reported by various authors. Other factors causing these variations could also be the strain and age of the animals.

The Influence of Bale Substrates on Performance

The majority of commercially reared conventional broiler chickens in many parts of the world are reared under high stocking densities with no enrichment objects, which inhibits their movement and contributes to poor welfare, especially regarding bone development. Weeks *et al.* (2000) reported that from



3 weeks of age, commercially reared broiler chickens show a marked reduction in activity levels, and from 39 days of age, they spend 76% to 80% of their time lying down. High levels of inactivity have been linked with an increase in the incidence and severity of leg problems (Kestin *et al.*, 1992; Prayitno *et al.*, 1997). Several studies have focused on different strategies to increase activity among broiler chickens, especially among fast-growing strains. The provision of bale substrates is one of the most efficient and feasible methods of increasing the activity of broiler chickens. In a research conducted by Kells *et al.* (2001), an increased activity among broiler chickens provided with straw bale was observed compared to those reared without straw bales. Bailie *et al.* (2013) also reported a lower percentage of average lying time and a higher percentage of average standing time among broiler chickens provided with straw bales compared to those reared without straw bales. However, the authors reported that no significant differences were recorded in the average time of resting, preening, eating, drinking, and aggressive behaviors. Furthermore, the percentage of hock burns, pododermatitis, culled broiler chickens, and slaughter weight were not affected by the presence or absence of straw bales. Moreover, Baxter *et al.* (2018) also reported the behavioral characteristics of broiler chickens housed with or without bales in the enriched areas of the house. The authors argued that while no significant differences were observed for pododermatitis, body weight, foraging, and resting behaviors, dual and single behaviors such as sitting but inactive, sitting and pecking, as well as sitting and preening were higher in those housed with bales. However, standing, preening and locomotion were lower in this group compared to the control. Mortality was also higher with the inclusion of bales compared to the control.

Lourenço da Silva *et al.* (2023) reported that the use of hay bales increased exploratory behavior more than the use of step platforms, with an increased usage of hay bales for resting as the broiler chickens aged. Moreover, chickens housed with hay bales had a higher prevalence of subclinical spondylolisthesis than those reared with perches. Nevertheless, the prevalence of subclinical spondylolisthesis did not differ between those reared with hay bales and the control.

Moc *et al.* (2022) also observed the combined influence of environmental enrichment (use of perches + straw bales) on the performance of fast-growing broiler strains. The authors reported that the moisture content of litter material in the enriched production

system with higher stocking density was lower than that of the production system with no enrichments. Furthermore, broiler chickens housed in the enriched production system had the highest body weight. However, the enrichment did not have any significant effect on mortality, footpad dermatitis, or hock burns.

Contrarily, other studies have observed either insignificant or negative effects of bale substrates as an environment object on performance and welfare traits of broiler chickens. For instance, Pedersen *et al.* (2020) reported that the provision of straw bales had no significant effect on the muscle width of the lower leg, femoral head necrosis, tibial dyschondroplasia, and twisted tibial. Tahamtani *et al.* (2020) reported poor footpad health in broiler chickens with access to straw bales compared to those provided with a 30 cm elevated platform. Other authors (Bach *et al.* 2019) also reported that standing, foraging and comforting behaviors were lower in the production system enriched with straw bales compared to other types of enrichment.

The differences in the results obtained by different authors related to the use of bale substrates as an enrichment object could be related to chicken strain, age, type of bale material, and height of the bale.

In summary, bale substrates as an enrichment object could be used to increase the locomotion, foraging, and exploratory behaviors of broiler chickens, which could also serve as a means of enhancing bone development. Furthermore, bales could be used to aid movement within the flock and to reduce trampling and other disturbances associated with crowding.

The Influence of Dustbathing Substrates on Performance

Dustbathing behaviors are considered one of the most important behaviors of chickens, since they are very important in the control of external parasites and excess feather lipids, and to keep the plumage in good condition in general. Dustbathing is a highly motivated behavior, and preventing broiler chickens from performing it could lead to severe stress. The fact that hens in battery cages show signs of dustbathing behavior has been taken to indicate that hens are highly motivated to dustbathe and that their welfare is compromised in production systems where dustbathing substrate is not provided (Olsson & Keeling, 2005). Similar situation could also apply to broiler chickens.

Furthermore, the provision of dustbathing substrates for broiler chicken is another method that could be used to increase exercise, leading to improvement



of the leg bones. When a chicken is dustbathing, it rotationally pushes its legs, so this behavior could be a form of exercise that improves the leg condition of broiler chickens, especially among fast-growing strains. The preference for dustbathing substrates by broiler chickens have been studied by Shields *et al.* (2004). The authors reported that broiler chickens performed significantly more vertical wing shaking per hour in the sand and spent a greater proportion of their total time in the sand than in rice hulls, paper, or wood shavings. In the same study, broiler chickens visited sand more frequently than paper or the wood shavings, whereas no dustbathing behavior was observed in rice hulls. Moreover, the latency to enter sand was significantly shorter than the latency to enter any of the other three substrates. However, the authors did not report any information on the effect of the various dustbathing substrates on growth performance or welfare traits. In a different study by Shields *et al.* (2005), it was identified that, when given a choice, broilers increasingly performed many of their behaviors in the sand. If only one litter type was provided, they performed those behaviors with similar frequency in sand or wood shavings, but no information on the effect of the various dustbathing substrates on growth performance or welfare were reported by the authors. Other authors (de Jong *et al.*, 2007) also identified similar observations with the preference for peat and sand being higher as dustbathing substrates. However, these substrates are expensive, unsustainable, and may interfere with the litter removal process (Baxter *et al.*, 2018). Although dustbathing may improve leg problems among chickens, Vestergaard & Sanotra (1999) reported that broiler chickens with tibial dyschondroplasia will dustbathe significantly less than their healthy counterparts, which may be due to the rotational movement of the legs during dustbathing that may cause severe pains and distress.

Baxter *et al.* (2018) conducted a comparative assessment of two different dustbathing substrates for commercial broiler chickens. The authors reported that the use of oat hull substrate was a successful enrichment strategy overall, promoting dustbathing and foraging behaviors as well as improving leg health. The authors also reported that although straw bales were attractive to broiler chickens, they did not promote much behavioral activity. Huang *et al.* (2009) also found a higher feed conversion ratio and daily gain in broiler chickens raised on coconut hulls compared with shavings. Moreover, Swain & Sundaram (2000) studied a coir dust of coconut husk as a litter material,

and despite some producers seeing it as an alternative to peat, they did not find either a positive or negative effect on performance with the use of this by-product. According to Vas *et al.* (2020), broiler chickens exposed to peat were quicker to stand, ground-scratch, and dustbathe, as well as quicker to peck at fresh peat compared to wood shavings.

In summary, the use of an appropriate substrate may increase dustbathing behavior, which could have an indirect effect on leg health. The lack of adequate information on the influence of dustbathing behavior on production and welfare performance makes this an interesting area for future investigation.

Future Research

During this review, it was observed that there is limited data on how perching, stocking density and outdoor access interact with the mechanism or compounds that influence meat quality traits. Furthermore, there is limited information on whether the use of bale substrates or the exhibition of dustbathing behavior has any influence on growth and welfare performance, as well as meat quality traits. It is recommended that further research should explore these areas, and provide the necessary link between the parameters mentioned above.

CONCLUSION

The improvement or enrichment of broiler production systems could serve as a potential means of enhancing growth and welfare performance, as well as carcass and meat quality traits of broiler chickens. The use of perches and platforms as enrichment objects improves movement within the flock, reducing overcrowding, stress, and the presence of clinical conditions. Similarly, regular ascend and descend movements from perches and platforms could serve as a medium to improve bone strength. However, the height of perches and platforms, and their design and materials should be given the necessary attention, as they may affect usage by broiler chickens. Exposure to outdoor access could serve as a potential strategy to prepare broiler chickens for various post-hatch environmental challenges, which could improve behavioral and physiological responses to various post-hatch environmental stimuli. Moreover, high stocking densities negatively affect production, welfare, carcass and meat quality traits of broiler chickens. However, the adjustment of the stocking density would have a positive effect on performance and welfare traits. The use of dustbathing and bale



substrates could also increase specific behaviors such as foraging and dustbathing, which could improve the overall affective state of the animals.

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Competing interests

The authors declare no competing interests.

Author contributions

Conceptualization, AN, BM, and KK; methodology, AN; data curation, AN; writing – original draft preparation, AN; writing – review and editing, AN; supervision, AN; All authors have read and agreed to the published version of the manuscript.

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