Effects of environmental complexity on welfare indicators of fast-growing broiler chickens

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ABSTRACT Increasing environmental complexity, e.g., by providing environmental enrichment, has been suggested as a way to increase activity levels and improve leg health in broilers. The aim of this study was to investigate the effects of different types of environmental complexity on leg health and measures of welfare of fast-growing broilers housed according to conventional European legislation. A total of 58 pens with approximately 500 broilers each (Ross 308), corresponding to a stocking density of 40 kg/m^2, were used. A total of 8 treatment groups, of which 5 were enrichment treatments (roughage, vertical panels, straw bales, and elevated platforms at 5 and 30 cm) and 3 were standard resources manipulations [increased distances between feed and water (7 m and 3.5 m), stocking density reduced to 34 kg/m^2, and 1 control group (1.5 m distance between feed and water and no enrichment objects)] were randomly assigned to each pen. At 35 D of age, 60 birds from each pen were assessed for gait, footpad dermatitis, hock burns, plumage cleanliness, presence of scratches, and leg deformities. Birds housed with 30 cm elevated platforms had worse gait compared to those housed with straw bales and at the lower stocking density of 34 kg/m^2 ($P = 0.004$ and $P = 0.001$). Broilers from the control group also had worse gait compared to those housed at 34 kg/m^2 stocking density. In addition, birds housed with access to a 30 cm elevated platform had healthier footpads compared to birds housed with access to straw bales ($P = 0.0001$) and with increased distance between feed and water ($P = 0.011$). Furthermore, birds housed with straw bales had worse footpad condition compared to birds with access to a 5 cm elevated platform ($P = 0.002$). There were no observed treatment effects on scratches, plumage cleanliness, leg deformities and body weight ($P > 0.05$). Based on the welfare indicators used in the present study, decreased stocking density has the potential of improving animal welfare, whereas the effects of elevated platforms need to be further studied before a final conclusion can be drawn, as footpad health was positively affected, but walking ability was impaired.

Key words: broiler chicken, environmental enrichment, welfare, gait score, contact dermatitis

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INTRODUCTION

One major challenge in today's production of conventional broiler chickens is leg health and lameness. Modern broilers are bred for fast growth and studies have reported an inactive time budget of approximately 80% (Weeks et al. 2000; Zuidhof et al., 2014). The combination of fast growth and inactivity contributes to the development of lameness and leg pathologies such as footpad dermatitis and likely results in reduced welfare for the birds, due to pain, and in economic losses for the farmer (Mayne et al. 2007; Gentle, 2011). The use of environmental enrichment has been demonstrated as a possible way to increase activity levels, improve leg health, and decrease the incidence of contact dermatitis in broiler chickens (reviewed by Riber et al., 2018). Environmental enrichment is defined as an improvement of the environment of captive animals that increases the behavioral opportunities of the animal and leads to an enhancement of its biological function (Newberry, 1995). Environmental enrichment acts by increasing the complexity of the environment, providing further opportunities for the performance of natural behaviors and increasing general activity levels. For example, straw bales increase environmental complexity by providing a novel object that can function as a source of foraging material, elevated resting space, increased all space, an obstacle the birds must navigate around and a potential way to hide from antagonistic interactions. Furthermore, environmental complexity can also be increased by simple manipulations of the environment, such as increasing distance between feed and water and creating a heterogeneous space where different resources are available in different areas of the pen.

Several types of environmental enrichment have shown positive effects on broiler chicken behavior and

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health. The availability of litter promotes foraging and dustbathing behavior, reducing inactivity (Arnould et al., 2004; Baxter and O'Connell, 2016). When broilers are reared in enriched pens with the opportunity to scratch and perch, significant improvements on activity level and leg health are observed (Jordan et al., 2011; Ventura et al., 2012). The provision of perches promotes increased endurance, stronger legs, decreased hock burns and footpad dermatitis, and a cleaner plumage (Ventura et al., 2010; Groves and Muir, 2013; Zhao et al., 2013). The provision of perches and vertical panels also reduces the incidence of disturbance events (Cornetto et al., 2002; Ventura et al., 2012), allowing the birds to have longer bouts of uninterrupted sleep. In addition, broilers show better distribution and use of available space when housed with vertical panels (Cornetto and Estevez, 2001). Broilers housed with straw bales show longer latency to lie and reduced lameness compared to broilers housed without straw bales (Bailie et al., 2013). Furthermore, fitting 30 cm elevated platforms has been shown to reduce the prevalence of lameness by approximately 7 percentage points and to lower the incidence and severity of leg pathologies (Kaukonen et al., 2017).

Improvements of welfare by manipulation of the environment or housing conditions may be accomplished in other ways than by adding environmental enrichment. For instance, increased distance between feeders and drinkers (2 m vs. 12 m) has been found to reduce lameness and mortality, increase the time spent standing, moving and foraging, and improve leg bone parameters (Reiter and Bessei, 2009). Moreover, a reduction of the stocking density can increase time spent running, scratching the litter, and performing comfort behavior such as wing flapping and leg stretching, and can reduce the severity of footpad dermatitis (Knierim, 2013).

Leg health problems can also have an impact on the productivity of the flock and the financial gain for the farmer. For example, lameness has been associated with mortality (Kittelsen et al., 2017), and contact dermatitis on the carcass can reduce the value of these at the slaughterhouse (Nygaard, 2016; Lund et al., 2017). In addition, increased activity, for example due to increased distance between resources, has been found to not affect feed efficiency or growth and to reduce the amount of fat in the carcass, improving meat quality (Ruiz-Feria et al., 2014). Therefore, developing environmental enrichment that is hygenic and practical has the potential to improve both broiler welfare and economic return for the producers.

Several studies have investigated the effects of environmental complexity on broiler welfare, but most studies compare only 1 or 2 treatments with a control group. Therefore, it is often difficult to compare the effects of different types of environmental complexity across studies due to differences in housing and management. The aim of this study was to investigate the effects of several types of environmental complexity on leg health and welfare of fast-growing broilers housed according to European legislation (Council Directive 2007/43/EC of 28 June 2007, European Commission, 2007). To this end, 8 different treatments varying with regard to environmental enrichment or complexity were allocated to pens of broiler chickens housed in an experimental facility simulating commercial conditions. The treatments either included vertical panels, maize roughage, bales of straw, elevated platforms, increased distance between feed and water, or reduced stocking density. It was predicted that the different treatments would have positive effects on gait score, contact dermatitis and/or other welfare measures compared to the control treatment. Furthermore, this study was part of a larger study, comparing the effects of environmental complexity on a range of other parameters, including learning ability, fearfulness, activity levels, leg bone strength, tibial dyschondroplasia, production parameters, etc. (Tahamtani et al., 2018b; Bach et al., 2019; Jones et al., in prep; Pedersen et al., in prep).

MATERIALS AND METHODS

Mixed-sex Ross 308 broilers were used in this study. The day-old chicks were acquired from a commercial hatchery (DanHatch A/S, Sønderborg, DK) and housed in 2 identical rooms in the same building of the experimental facilities at Aarhus University, Foulum. The rooms measured 10.7 m × 16.6 m, and each room was equipped with 5 pens of 9.6 m × 3.1 m (29.8 m^2). Commercial conditions were simulated by keeping the stocking density at slaughter at 40 kg/m^2. At 1 D of age, the light schedule was programmed for 23L: 1D. Subsequently, every day, 1 h of darkness was added to the light program until 18L: 6D was reached on day 6 of age, which was maintained until the end of life at day 35 of age. The light intensity was approximately 27.5 lux. The feed and feeding program used were recommended by the commercial feed company DLG (Tjele, DK). Feed was made available ad libitum in round feeders (1.61 cm of feeder space per bird). The number of broilers per water nipple was 11.7 (range 11.6 to 11.8). A 4-cm layer of wood shavings covered the floor in each pen. All flocks were slaughtered at 35 D of age.

Experimental Treatments

A total of 9 experimental groups (8 treatment groups and 1 control group) were used in the present study (Figure 1). The study was performed in 6 blocks, which consisted of a repetition of the experimental treatments in order to increase the number of treatment replicates. In each block, 9 experimental groups were randomly assigned to 10 pens in 2 identical experimental rooms. In each block, 1 experimental group was assigned to 2 pens. For example, the tenth pen was used for the control group in 1 block and for an experimental treatment in another block. This resulted in 6 to 8 replicates per treatment (Table 1). Following random allocations, the treatments were balanced across 2 adjacent rooms to

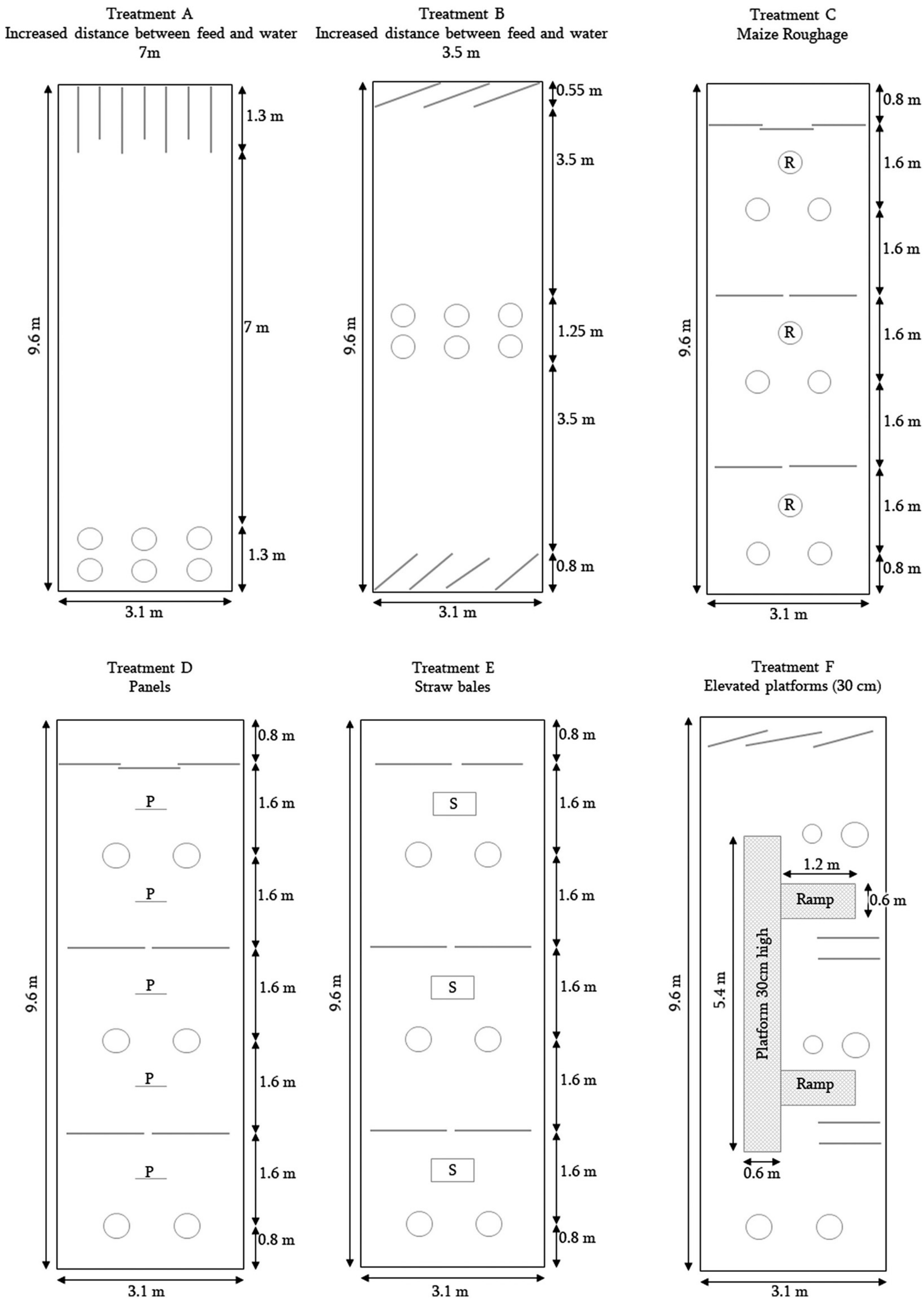

Figure 1. Schematic illustration of each treatment pen. Grey circles represent round feeders. Grey lines represent the water line with drinking nipples. Circles labeled "R" in treatment C represent circular pans used for the allocation of maize roughage. Lines labeled "P" in treatment D represent opaque vertical panels. Rectangles labeled "S" in treatment E represent straw bales. Figure reproduced from Tahamtani et al. (2018b).

preclude any confounding effects of the rooms. Due to minor flooding during block 1, 2 pens from that block had to be excluded from the data, resulting in a total of 58 pens across all 6 blocks. This resulted in a total of 27,551 broilers being included in this study.

Treatments A and B consisted of increased distances between the feed troughs and the drinking nipples of 7 m and 3.5 m, respectively. To ensure early feed uptake, 1 of the feed troughs was placed 1.5 m from the water lines on days 0 to 2, then moved to 3.5 m from the water lines on day 3, and, for treatment A, finally moved to 7 m from the water lines on day 5. In treatment A, due to the birds growing to occupy most of the floor space in the pen, the distance between feed

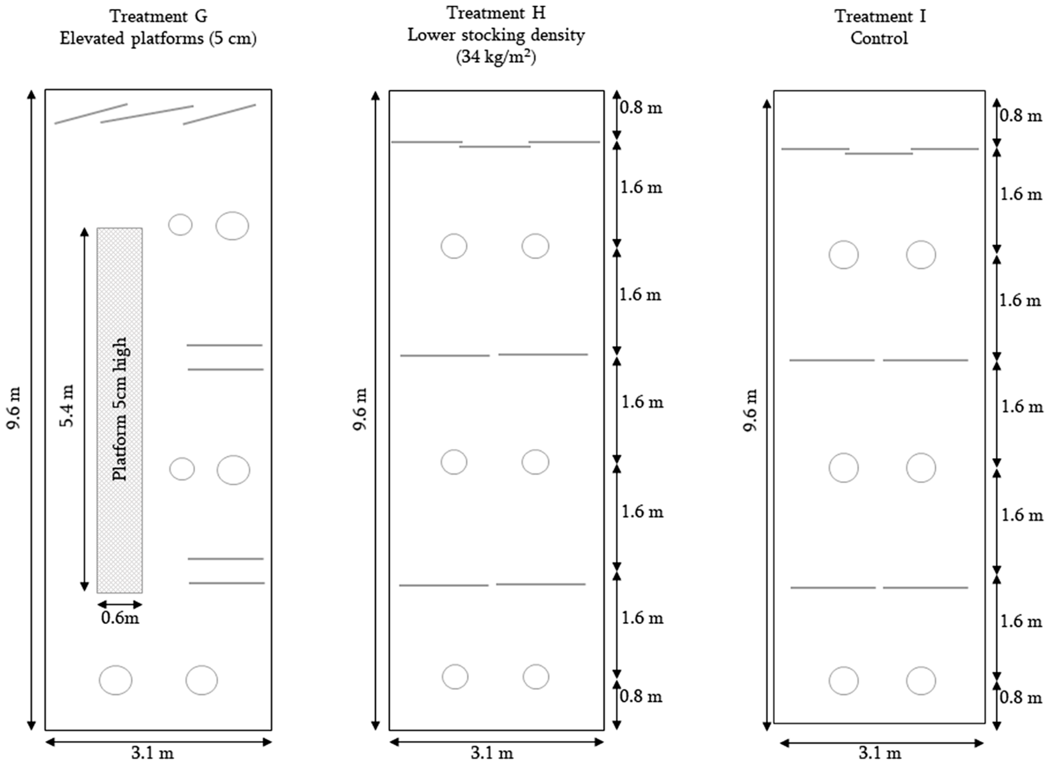

Figure 1. *Continued.*

Table 1. Experimental groups, flock size per group, and total number of replicates for each treatment across all 6 blocks.

Experimental group code	Treatment	Flock size/pen	No. of replicates
A	Distance between feed and water – 7 m	497	6
B	Distance between feed and water – 3.5 m	497	6
C	Maize roughage	497	7
D	Vertical panels	497	6
E	Bales of straw	482	7
F	Platform at 30 cm height and access ramps	437	6
G	Platform at 5 cm height, no access ramps	437	6
H	Lower stocking density (34 kg/m^2)	422	6
I	Control	497	8

Treatments: A- 7 m distance between feed and water; B- 3.5 m distance between feed and water; C- maize roughage; D- vertical panels; E- straw bales; F- 30 cm elevated platform; G- 5 cm elevated platform; H- low stocking density; and I- control.

and drinking nipples was reduced to 1.5 m from 22 D of age until slaughter to ensure the birds would not be deprived of food or water. In treatment B, the distance between feed and water was kept at 3.5 m throughout the life of the flock. In all other experimental groups, the distance between feeders and drinkers was 1.5 m. Treatment C included the allocation of a high-fiber feed supplement in the form of maize roughage in addition to the ad libitum standard feed. This roughage was provided daily throughout the broilers' life in 3 circular pans (ø 0.4 m), distributed evenly across the pen. The amount of roughage allocated was visually monitored daily to last during the entire day until the next allocation. In treatment D, 5 non-transparent vertical panels (60 cm × 60 cm) were placed in the central area of the pens, evenly distributed. In treatment E, 3 bales of non-chopped long stemmed straw of 42 cm × 40 cm × 70 cm (height × width × length) were evenly distributed across the pens. Both panels and straw bales were present upon placement of the broilers. The bales were fully exposed to the chickens (i.e., not wrapped in plastic) but were held in shape by 2 twine strings and, therefore, did not collapse during the life of the broilers. Fresh bales of straw were provided for every block. In treatments F and G, perforated plastic slats were provided as elevated platforms (5.4 m × 0.6 m) which the birds could easily access and occupy. In treatment F, the platform was mounted at a height of 30 cm above the bedding and included 2 ramps at an incline of 14.5° for ease of access. The area underneath the platform was fenced off and not accessible to the birds in order to maintain the stocking density at 40 kg/m^2. In treatment G, the height of the platforms was 5 cm above the bedding and did not include access ramps. Treatment H consisted of a lower stocking density of 34 kg/m^2, whereas all other treatments carried a stocking density of 40 kg/m^2. Other than stocking density, the conditions in treatment H were the same as in experimental group I. In the control group (I), the broilers were housed under commercial-like conditions without access to elevated resting places, no roughage supplement, no panels, no straw bales, with a distance of 1.5 m between

Table 2. The Bristol scale for gait scoring (after Kestin et al., 1992).

Gait score	Criteria
GS0	No detectable abnormality, fluid motion.
GS1	Slight defect. Difficult to define.
GS2	Definite and identifiable defect, but it does not hinder movement.
GS3	An obvious gait defect that affects the broiler's ability to manoeuvre and accelerate.
GS4	A severe gait defect. The broiler will only walk a couple of steps if driven before sitting down.
GS5	Complete lameness. Either cannot walk or cannot support weight on the legs.

feed and drinking nipples, and at a stocking density of 40 kg/m^2. When calculating the flock size per pen to achieve 40 kg/m^2, the area of the pen occupied by the enrichment objects was subtracted from the total floor area of the pen. This was done in accordance with EU regulations specifying that the useable area must be covered by litter (EU Council Directive 2007/43/EC of 28 June 2007, European Commission, 2007). Therefore, the area occupied by the elevated platforms and straw bales does not count as useable area. To account for the resulting difference in flock size per experimental group, the number of drinking nipples and feeding space per bird was also controlled to preclude any confounding effects of diminished competition for resources.

Data Collection

Individual BW was measured from 100 birds per pen at days 0, 7, 21, and 35 of age. At 35 D of age, 60 birds from each pen were assessed for gait score, footpad dermatitis, hock burns, plumage cleanliness, presence of scratches, and leg deformities (varus or valgus). The birds were assessed by 3 experienced observers. The observers were trained together on how to differentiate between each score using live birds, video recordings, and photographs while discussing different cases. Inter and intra-observer reliability tests were performed based on gait scores of broilers from 36 different videos. In addition, each observer scored each video on 3 separate occasions. The observers were found to have moderate levels of agreement between each other (kappa value 0.41 to 0.60) and substantial levels of agreement with themselves across time (kappa value 0.61 to 0.80).

Walking ability, or gait, was scored according to the Bristol scale, from 0 (normal gait, dexterous, and agile) to 5 (incapable of walking) (Table 2; Kestin et al., 1992). Footpad dermatitis was scored on a 3-point scale from 0 (no injury) to 2 (serious injury) (Ekstrand et al., 1998). Hock burns were scored on a 4-point scale from 0 (no injury) to 3 (heavy crust formation on >10% of the hock; Sherlock et al., 2010). The presence of scratches and leg deformities, varus, and valgus, was scored on a dichotomous scale (Yes/No). Cleanliness of the plumage was scored on a 4-point scale from 0 (very clean) to 3 (very dirty) according to the Welfare Quality assessment protocol for poultry (Welfare Quality, 2009). As the treatments were all located in the same 2 rooms, collection of data on the air quality for the different treatment groups was not possible. Furthermore, no data on litter quality was collected.

Ethical Statement

All procedures involving animals were approved by the Danish Animal Experiments Inspectorate in accordance with the Danish Ministry of Justice Law number 382 (June 10, 1987) and Acts 333 (May 19, 1990), 726 (September 9, 1993), and 1016 (December 12, 2001). The birds were visually inspected daily by trained staff. If any bird was seen in obvious distress (e.g., unable to stand on both legs or walk), it was immediately removed from the experimental room and culled by cervical dislocation.

Statistical Analysis

All data analyses were performed using the statistical software SAS 9.3. Footpad dermatitis and hock burn scores for the left and right foot were averaged per bird. The effects of experimental treatment on footpad dermatitis and on hock burns were tested using the GLIMMIX procedure with a Gaussian distribution, pen as a random factor nested in block, and treatment as a fixed factor. The variable observer was also included in the model as a random factor to account for any inter-observer differences. Where a significant effect of treatment was found, post hoc comparisons of treatments were performed using Tukey's test (Tukey's HSD test).

The data on gait score were analyzed using a multinomial GLIMMIX procedure with the random factor pen nested in block and treatment as the fixed effect. The critical P-value associated with the analysis of gait score was Bonferroni corrected to $P = 0.0014$. The effects of type of enrichment on the prevalence of scratches were tested using a binary GLIMMIX procedure with random factor pen nested in block and treatment as a fixed factor. The variable observer was also included in the model as a random factor to account for any inter-observer differences. The BW data were log transformed to meet the assumptions of the model and were analyzed using the mixed procedure with the random factor pen nested in block and treatment as well as age (0, 7, 21, and 35 D of age) as the fixed factors. The interaction between treatment and age was also included in the model. All results are reported as least square means and standard errors. The least square means for BW are back transformed.

Data on dirtiness and leg deformities (varus and valgus) could not be statistically analyzed due to the vast majority of birds obtaining the same score and, regarding leg deformities, very few observed cases. For these parameters, only descriptive statistics are presented.

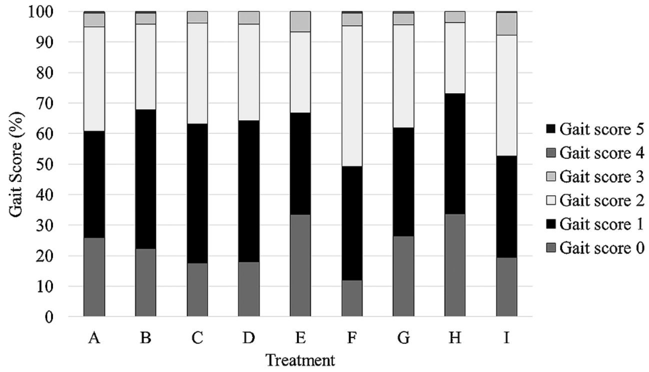

Figure 2. Percentage distribution of gait scores across the experimental groups. Treatments: A- 7 m distance between feed and water; B- 3.5 m distance between feed and water; C- maize roughage; D- vertical panels; E- straw bales; F- 30 cm elevated platform; G- 5 cm elevated platform; H- low stocking density; and I- control.

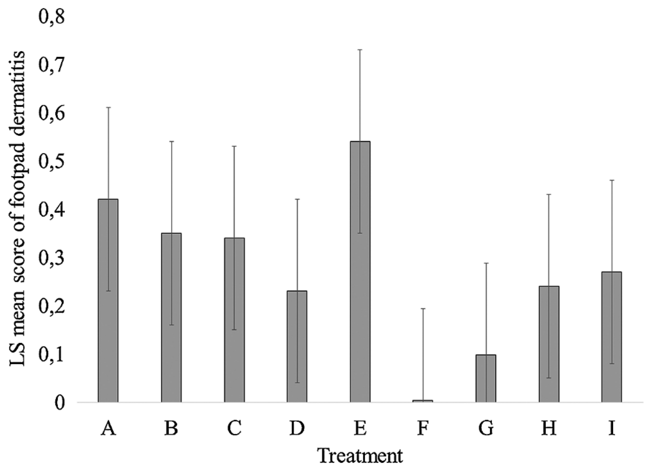

Figure 3. Least square mean ± SE scores of footpad dermatitis across experimental groups. Treatments: A- 7 m distance between feed and water; B- 3.5 m distance between feed and water; C- maize roughage; D- vertical panels; E- straw bales; F- 30 cm elevated platform; G- 5 cm elevated platform; H- low stocking density; and I- control.

RESULTS

An overall effect of treatment was observed on gait score ($F_{8,\ 3418} = 2.20$; $P = 0.024$; Figure 2) with broilers from treatment F (30 cm elevated platform) having 0.35 times lower estimated odds of having a lower mean gait score compared to broilers from treatment H (reduced stocking density; $P = 0.001$). In addition, there was a tendency for treatment E (straw bales) to have a lower gait score compared to treatment F (30 cm elevated platform; $P = 0.004$) and for treatment H (reduced stocking density) to have a lower gait score compared to the control group (treatment I, $P = 0.003$). There was an effect of treatment on footpad dermatitis ($F_{8,\ 3420} = 3.93$; $P = 0.0001$; Figure 3; Supplementary information available in the appendix in Table A1). Post hoc Tukey revealed that birds from treatment F (30 cm elevated platform) had lower scores of footpad dermatitis compared to birds from treatment A (7 m between feed and water; $P = 0.011$) and from treatment E (straw bales; $P = 0.0001$). Birds from treatment E also had higher

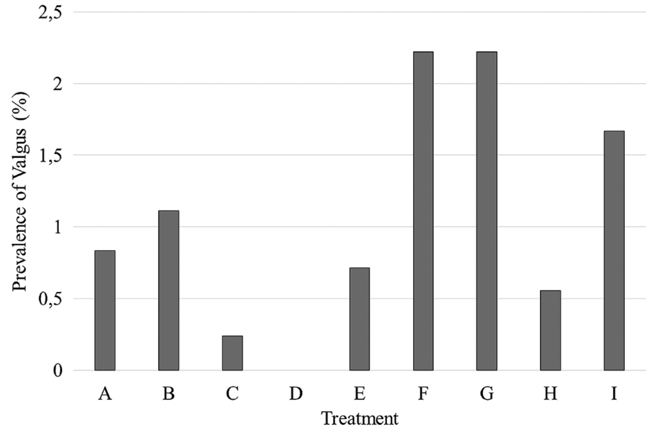

Figure 4. Prevalence (%) of valgus deformity (outward twist) of the tibia across the treatments. Treatments: A- 7 m distance between feed and water; B- 3.5 m distance between feed and water; C- maize roughage; D- vertical panels; E- straw bales; F- 30 cm elevated platform; G- 5 cm elevated platform; H- low stocking density; and I-control.

scores compared to birds from treatment G (5 cm elevated platform; $P = 0.002$). In addition, there was a trend for birds from treatment F (30 cm elevated platform) to have lower footpad dermatitis scores compared to birds from treatment B (3.5 m between feed and water; $P = 0.067$). There was also a trend for birds from treatment C (maize roughage) to have higher footpad scores compared to birds from treatment F (30 cm elevated platform; $P = 0.081$). A tendency for treatment effects on hock burns was found (LS mean range ± SE = 0.34 to 0.70 ± 0.22; $F_{8,\ 3420} = 1.90$; $P = 0.055$; Supplementary information available in the appendix in Table A1).

Only 1 case of varus deformity was observed (in treatment D, vertical panels). Few cases of valgus deformities were seen with treatments F (30 cm elevated platform) and G (5 cm elevated platform) presenting the largest numerical percentages of observed cases (2.2%) and treatment D (vertical panels) presenting 0 cases (Figure 4). In regards to dirtiness, the vast majority of birds from all treatments gained a dirtiness score of 1 (range: 73.0 to 99.4%). The treatment with the highest number of score 0 was treatment H (reduced stocking density; 2.2%), while the one with the highest number of score 2 was treatment C (maize roughage; 26.4%; Figure 5). There was no effect of treatment on the prevalence of scratches ($F_{8,\ 3420} = 1.13$; $P = 0.37$).

The model on BW showed a significant interaction between treatment and age ($F_{24,\ 24\hat{}3} = 4.91$; $P < 0.0001$; Figure 6). However, post hoc Tukey revealed that this effect was only due to differences between treatments at different age points and not between treatments at the same age ($df = 56.9$; $-2.24 < t < 1.17$; $P > 0.05$).

DISCUSSION

The results show the effects of different types of environmental enrichment on parameters commonly

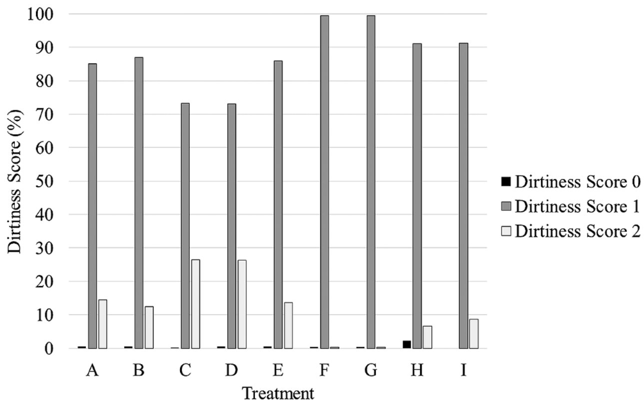

Figure 5. Percentage distribution of dirtiness scores across the treatments. Treatments: A- 7 m distance between feed and water; B- 3.5 m distance between feed and water; C- maize roughage; D- vertical panels; E- straw bales; F- 30 cm elevated platform; G- 5 cm elevated platform; H- low stocking density; I- control.

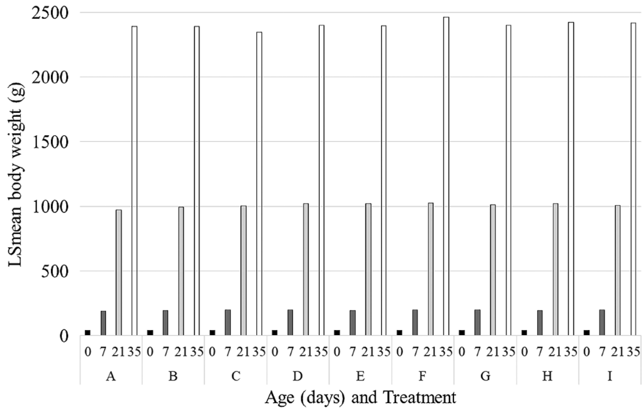

Figure 6. Least square mean (back transformed) of BW (g) at 0, 7, 21, and 35 D of age across all experimental groups. Treatments: A- 7 m distance between feed and water; B- 3.5 m distance between feed and water; C- maize roughage; D- vertical panels; E- straw bales; F- 30 cm elevated platform; G- 5 cm elevated platform; H- low stocking density; and I- control.

measured in a welfare assessment protocol for broilers, including contact dermatitis and gait score. Fast-growing broilers housed with access to a 30 cm elevated platform (treatment F) developed less footpad dermatitis compared to broilers housed with 7 m distance between feed and water (treatment A). This is likely due to the fact that birds with access to elevated platforms have the opportunity to spend less time standing and lying on the litter, as they can move onto the platforms. A well-known risk factor for footpad dermatitis is humid and ammonia-soiled litter (Ekstrand et al., 1997, 1998). In addition, these tall platforms allow for the circulation of air under the birds, which likely promotes drying of wet skin and feathers. Indeed, the same effect was not seen on broilers housed with a 5 cm elevated platform where the small space between the floor and the platform was eventually filled up by the droppings from the birds.

Previously, it has been shown that scratching behavior is beneficial to the litter quality (de Jong et al., 2013). This might have been a second explanation for the difference in footpad dermatitis between the birds housed with elevated platforms and those housed with increased distance between feed and water. One could have expected that the birds housed with a large distance between feed and water spent more of their activity budget in locomotion between the feed and water, and less time scratching the litter, resulting in a top layer of litter wet and dense with droppings. However, while birds housed with increased distances between feed and water had higher overall activity than the others, we were not able to show that the treatments differed in the time spent in locomotion or foraging (Bach et al., 2019). Furthermore, another study found that increased distance between feed and water actually increased the time the birds spent foraging (Reiter and Bessei, 2009). Unfortunately, we did not collect data on the quality of the litter and therefore cannot confirm any predictions of the effects of the treatments on litter quality.

The results also showed a tendency for birds provided with maize roughage to have more footpad dermatitis than those housed with 30 cm elevated platforms. No previous studies exist on allocation of roughage for conventional broilers. However, previous studies have shown that scattering whole wheat or wood shavings on the litter does not change the broilers' time budget or increase foraging activity (Bizeray et al., 2002; Jordan et al., 2011; Pichova et al., 2016). On the other hand, when mealworms which is a highly valued food by the chickens, are scattered in the litter there is a significant increase in litter pecking and litter scratching (Pichova et al., 2016). In the present study, footpad dermatitis was also more common in birds housed with straw bales compared to birds housed with elevated platforms. This was expected, as previous studies have identified straw, particularly unchopped straw, as a risk factor for the development of footpad dermatitis due to its effect on the moisture content of the litter (Sirri et al., 2007; Bilgili et al., 2009; Đukić Stojčić et al., 2016).

In regards to gait score, birds housed with access to a 30 cm elevated platform with access ramps had lower odds of having a low gait score (i.e., good walking ability) compared to birds housed at 34 kg/m^2 stocking density. Taking into account the low mean scores of footpad dermatitis in broilers housed with a 30 cm elevated platform, the results for the gait score suggest that footpad dermatitis may not have been the major cause of walking difficulties in these birds. Sørensen et al. (2000) showed a correlation between footpad dermatitis and lameness, but others have not found this link (Kristensen et al., 2006; Haslam et al., 2007). It is largely accepted that high stocking density affects the growth rate of broilers, mainly through heat stress and poor litter quality (for a review see Bessei, 2006). However, according to the results on BW, we know that these differences between treatments in walking ability were not due to differences in the BW gain of the birds. Nevertheless, high stocking density is known to increase the risk of walking difficulties through behavioral restriction (Knierim, 2013). Knierim (2013) compared walking ability, footpad dermatitis and behavior of broilers housed at 18, 25, 35, and 40 kg/m^2 stocking densities. It was observed that footpad dermatitis and walking difficulties were more prevalent and severe at higher densities, and that at lower densities the broilers performed more wing lifting, wing-leg stretching, running, scratching of the litter, and scratching of their own body. These results suggest that at lower stocking densities broilers have more space to move and exercise, promoting leg health (Knierim, 2013).

Overall, the birds in our study had predominantly low gait scores. Over 90% of the birds from every treatment scored GS0, GS1, or GS2 during the assessment at 35 D of age. Scores of GS0 and GS1 constituted over 50% of the birds from every treatment, except treatment F (30 cm elevated platform), and going as high as 73% in treatment H (reduced stocking density). In addition, the prevalence of GS3 or higher (i.e., the bird had obvious gait defect) was quite low, ranging from 3.6 to 7.7%. These numbers are similar to those recently seen in broilers in conventional Danish broiler production. A survey of walking ability in Danish conventional broilers in 2016/2017 reported a national average of 4.7%, 0.6%, and 0.1% of birds with GS3, GS4, and GS5, respectively (Tahamtani et al., 2018a). However, a prevalence of 25% of broilers with GS $\geq$ 3 was recently reported from Norway (Kittelsen et al., 2017). Likewise, a high prevalence of GS $\geq$ 3 has been found in a study including 89 flocks with genotypes Ross 308, Cobb, and mixed Ross and Cobb from France, UK, the Netherlands, and Italy (Bassler et al., 2013). In Brazil, with mixed sex Cobb broilers, 3.6% of broilers have GS4 or GS5 (Souza et al., 2015). One could expect that the effect of environmental enrichment on gait might be more discernible if the prevalence of lameness (GS $\geq$ 3) is higher, like in these cases cited. Indeed, in a recent on-farm study in Finland, 29% of the fast-growing broilers housed without access to platforms had a GS3 (Kaukonen et al., 2017). Fitting platforms into the conventional farms reduced the prevalence of GS3 to approximately 22% as well as resulted in a lower mean gait score and lower incidence and severity of tibial dyschondroplasia (Kaukonen et al., 2017). Therefore, while our results showed no positive effect of platforms compared to the control on gait score, perhaps these results would have been different if the prevalence of GS3 in our birds had been larger. It is also important to note the positive impact that reduced stocking density can have on walking ability of fast-growing broilers. In our study, the stocking densities used were approximately 40 kg/m^2 and 34 kg/m^2. In their study, Kaukonen et al. (2017) housed broilers at 42 kg/m^2. It is likely that some of the discrepancy between these results on gait score is due to this difference in stocking density. Something similar could be expected in regards to footpad dermatitis, with the present results perhaps not showing more effects of the treatments on footpad dermatitis, particularly in comparison to the control group because the overall scores were low. Another factor that might have caused the gait scores in our study to be generally low was the fact that any birds in obvious distress due to lameness (e.g., unable to stand on both legs or walk) were culled during the daily inspections of the flocks. However, there was no effect of the treatments on the mortality rate of the birds (Jones et al., in prep).

In conclusion, the results from the present study support the previous findings that reduced stocking density has the potential to improve walking ability in fast-growing broilers. Furthermore, the observed effects of the different types of environmental enrichment and environmental modification suggest that the provision of straw, time in contact with the litter, and reduced scratching of the litter may be risk factors for the development of footpad dermatitis. Based on the welfare indicators used in the present study, decreased stocking density has the potential of improving animal welfare, whereas the effects of elevated platforms need to be further studied before a final conclusion can be drawn, as footpad health was positively affected, but walking ability was impaired, although not in comparison with the control group. Finally, as this study was performed in an experimental facility with small flock sizes, an important next step would be to test these types of environmental enrichment and manipulations on large-scale conventional farms, both to confirm the effects reported here and to investigate any further effects in on-farm broiler production.

SUPPLEMENTARY DATA

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.3382/ps/pez510.

Table S1. Sample size, least square mean scores and standard errors of footpad dermatitis and hocks burns across treatments.

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REFERENCES

Arnould, C., D. Bizeray, J. M. Faure, and C. Leterrier. 2004. Effects of the addition of sand and string to pens on use of space, activity, tarsal angulations and bone composition in broiler chickens. Anim. Welf. 13:87–94.

Bach, M. H., F. M. Tahamtani, I. J. Pedersen, and A. R. Riber 2019. Effects of environmental complexity on behaviour in fast-growing broiler chickens. Applied Animal Behaviour Science. 219. doi: 10.1016/j.applanim.2019.104840

Bailie, C. L., M. E. E. Ball, and N. E. O'Connell. 2013. Influence of the provision of natural light and straw bales on activity levels and leg health in commercial broiler chickens. Animal. 7:618–626.

Bassler, A. W., C. Arnould, A. Butterworth, L. Colin, I. C. De Jong, V. Ferrante, P. Ferrari, S. Haslam, F. Wemelsfelder, and H. J. Blokhuis. 2013. Potential risk factors associated with contact dermatitis, lameness, negative emotional state, and fear of humans in broiler chicken flocks. Poult. Sci. 92:2811–2826.

Baxter, M., and N. E. O'Connell. 2016. Commercial comparison of potential dustbathing substrates for intensively farmed broilers. Proc. EAAP 67th Annual Meeting Belfast, Northern Ireland. Aug. 29−Sept. 1.

Bessei, W. 2006. Welfare of broilers: a review. Worlds Poult. Sci. J. 62:455–466.

Bilgili, S. F., J. B. Hess, J. P. Blake, K. S. Macklin, B. Saenmahayak, and J. L. Sibley. 2009. Influence of bedding material on footpad dermatitis in broiler chickens. J. Appl. Poult. Res. 18:583–589.

Bizeray, D., I. Estevez, C. Leterrier, and J. M. Faure. 2002. Effects of increasing environmental complexity on the physical activity of broiler chickens. Appl. Anim. Behav. Sci. 79:27–41.

Cornetto, T., and I. Estevez. 2001. Influence of vertical panels on use of space by domestic fowl. Appl. Anim. Behav. Sci. 71:141–153.

Cornetto, T., I. Estevez, and L. W. Douglass. 2002. Using artificial cover to reduce aggression and disturbances in domestic fowl. Appl. Anim. Behav. Sci. 75:325–336.

de Jong, I. C., B. F. J. Reuvekamp, and H. Gunnink. 2013. Can substrate in early rearing prevent feather pecking in adult laying hens? Anim. Welf. 22:305–314.

Đukić Stojčić, M., S. Bjedov, D. Žikić, L. Perić, and N. Milošević. 2016. Effect of straw size and microbial amendment of litter on certain litter quality parameters, ammonia emission, and footpad dermatitis in broilers. Arch. Anim. Breed. 59:131–137.

Ekstrand, C., B. Algers, and J. Svedberg. 1997. Rearing conditions and foot-pad dermatitis in Swedish broiler chickens. Prev. Vet. Med. 31:167–174.

Ekstrand, C., T. E. Carpenter, I. Andersson, and B. Algers. 1998. Prevalence and control of foot-pad dermatitis in broilers in Sweden. Br. Poult. Sci. 39:318–324.

European Commission. 2007. Council Directive 2007/43/EC of 28 June 2007 laying down minimum rules for the protection of chickens kept for meat production. Pages 19–28 in Official Journal of the European Union. E. Union ed. European Commission.

Gentle, M. J. 2011. Pain issues in poultry. Appl. Anim. Behav. Sci. 135:252–258.

Groves, P. J., and W. I. Muir. 2013. Commercial comparison of potential dustbathing substrates for intensively farmed broilers. Proc. 9th European Symposium on Poultry Welfare, Uppsala, Sweden. June 17−20.

Haslam, S. M., T. G. Knowles, S. N. Brown, L. J. Wilkins, S. C. Kestin, P. D. Warriss, and C. J. Nicol. 2007. Factors affecting the prevalence of foot pad dermatitis, hock burn and breast burn in broiler chicken. Br. Poult. Sci. 48:264–275.

Jordan, D., I. Stuhec, and W. Bessei. 2011. Effect of whole wheat and feed pellets distribution in the litter on broilers' activity and performance. Archiv Fur Geflugelkunde. 75:98–103.

Kaukonen, E., M. Norring, and A. Valros. 2017. Perches and elevated platforms in commercial broiler farms: use and effect on walking ability, incidence of tibial dyschondroplasia and bone mineral content. Animal. 11:864–871.

Kestin, S. C., T. G. Knowles, A. E. Tinch, and N. G. Gregory. 1992. Prevalence of leg weakness in broiler-chickens and its relationship with genotype. Vet. Rec. 131:190–194.

Kittelsen, K. E., B. David, R. O. Moe, H. D. Poulsen, J. F. Young, and E. G. Granquist. 2017. Associations among gait score, production data, abattoir registrations, and postmortem tibia measurements in broiler chickens. Poult. Sci. 96:1033–1040.

Knierim, U. 2013. Effects of stocking density on the behaviour and bodily state of broilers fattened with a target live weight of 2 kg. Berl. Munch. Tierarztl. Wochenschr. 126:149–155.

Kristensen, H. H., G. C. Perry, N. B. Prescott, J. Ladewig, A. K. Ersboll, and C. M. Wathes. 2006. Leg health and performance of broiler chickens reared in different light environments. Br. Poult. Sci. 47:257–263.

Lund, V. P., L. R. Nielsen, A. R. S. Oliveira, and J. P. Christensen. 2017. Evaluation of the Danish footpad lesion surveillance in conventional and organic broilers: misclassification of scoring. Poult. Sci. 96:2018–2028.

Mayne, R. K., R. W. Else, and P. M. Hocking, 2007. High litter moisture alone is sufficient to cause footpad dermatitis in growing turkeys. Br. Poult. Sci. 48:538–545.

Newberry, R. C. 1995. Environmental enrichment − increasing the biological relevance of captive environments. Appl. Anim. Behav. Sci. 44:229–243.

Nygaard, C. 2016. Danish achievements on foot pad lesions in broilers. Pages 483 in The XXV World's Poultry Congress. N. Yang ed. The World's Poultry Science Association, Beijing, China.

Pichova, K., J. Nordgreen, C. Leterrier, L. Kostal, and R. O. Moe. 2016. The effects of food-related environmental complexity on litter directed behaviour, fear and exploration of novel stimuli in young broiler chickens. Appl. Anim. Behav. Sci. 174:83–89.

Reiter, K., and W. Bessei. 2009. Effect of locomotor activity on leg disorder in fattening chicken. Berl. Munch. Tierarztl. Wochenschr. 122:264–270.

Riber, A. B., H. A. van de Weerd, I. C. de Jong, and S. Steenfeldt. 2018. Review of environmental enrichment for broiler chickens. Poult. Sci. 97:378–396.

Ruiz-Feria, C. A., J. J. Arroyo-Villegas, A. Pro-Martinez, J. Bautista-Ortega, A. Cortes-Cuevas, C. Narciso-Gaytan, A. Hernandez-Cazares, and J. Gallegos-Sanchez. 2014. Effects of distance and barriers between resources on bone and tendon strength and productive performance of broiler chickens. Poult. Sci. 93:1608–1617.

Sherlock, L., T. G. M. Demmers, A. E. Goodship, I. D. Mccarthy, and C. M. Wathes. 2010. The relationship between physical activity and leg health in the broiler chicken. Br. Poult. Sci. 51:22–30.

Sirri, F., G. Minelli, E. Folegatti, S. Lolli, and A. Meluzzi. 2007. Foot dermatitis and productive traits in broiler chickens kept with different stocking densities, litter types and light regimen. Ital. J. Anim. Sci. 6:734–736.

Souza, A. P. O., E. Sans, B. R. Muller, and C. F. M. Molento. 2015. Broiler chicken welfare assessment in GLOBALGAP (R) certified and non-certified farms in Brazil. Anim. Welf. 24:45–54.

Sørensen, P., G. Su, and S. C. Kestin. 2000. Effects of age and stocking density on leg weakness in broiler chickens. Poult. Sci. 79:864–870.

Tahamtani, F. M., L. K. Hinrichsen, and A. B. Riber. 2018a. Welfare assessment of conventional and organic broilers in Denmark, with emphasis on leg health. Vet. Rec. 183:192.

Tahamtani, F. M., I. J. Pedersen, C. Toinon, and A. B. Riber. 2018b. Effects of environmental complexity on fearfulness and learning ability in fast growing broiler chickens. Appl. Anim. Behav. Sci. 207:49–56.

Ventura, B. A., F. Siewerdt, and I. Estevez. 2010. Effects of barrier perches and density on broiler leg health, fear, and performance. Poult. Sci. 89:1574–1583.

Ventura, B. A., F. Siewerdt, and I. Estevez. 2012. Access to barrier perches improves behavior repertoire in broilers. PLoS ONE. 7:7.

Weeks, C. A., T. D. Danbury, H. C. Davies, P. Hunt, and S. C. Kestin. 2000. The behaviour of broiler chickens and its modification by lameness. Appl. Anim. Behav. Sci. 67:111–125.

Welfare Quality, 2009. Welfare Quality assessment protocol for poultry (Broilers, laying hens). Welfare Quality® Consortium, Lelystad, Netherlands.

Zhao, J. P., H. C. Jiao, Y. B. Jiang, Z. G. Song, X. J. Wang, and H. Lin. 2013. Cool perches improve the growth performance and welfare status of broiler chickens reared at different stocking densities and high temperatures. Poult. Sci. 92:1962–1971.

Zuidhof, M. J., B. L. Schneider, V. L. Carney, D. R. Korver, and F. E. Robinson 2014. Growth, efficiency, and yield of commercial broilers from 1957, 1978 and 2005. Poult. Sci. 93:2970–2982.