Animal 15 (2021) 100109

Contents lists available at ScienceDirect

Animal
The international journal of animal biosciences

Influence of a raised slatted area in front of the nest on leg health, mating behaviour and floor eggs in broiler breeders

A.C.M. van den Oever [a,b,*], L. Candelotto [c], B. Kemp [b], T.B. Rodenburg [b,d], J.E. Bolhuis [b], E.A.M. Graat [b], L.J.F. van de Ven [a], D. Guggisberg [e], M.J. Toscano [c]

[a] Vencomatic Group, P.O. Box 160, 5520 AD Eersel, the Netherlands
[b] Adaptation Physiology Group, Wageningen University, P.O. Box 338, 6700 AH Wageningen, the Netherlands
[c] Centre for Proper Housing: Poultry and Rabbits (ZTHZ), Division of Animal Welfare, VPH Institute, University of Bern, Burgerweg 22, 3052 Zollikofen, Switzerland
[d] Animals in Science and Society, Faculty of Veterinary Medicine, Utrecht University, P.O. Box 80.166, 3508 TD Utrecht, the Netherlands
[e] Agroscope, Food Microbial Systems, Nutrition, Flavour, Aroma and Physical Analytics Group, Schwarzenburgstrasse 161, 3003 Bern, Switzerland

ARTICLE INFO

Article history:
Received 2 July 2020
Received in revised form 7 October 2020
Accepted 8 October 2020
Available online 16 December 2020

Keywords:
Copulations
Foot pad dermatitis
Housing
Poultry
Production performance

ABSTRACT

European farms for broiler breeders often have raised slatted areas in front of the nests, but in other regions of the world no raised slatted areas are provided. This study aimed to investigate the effects of a raised slatted area on leg health, mating behaviour and floor laying behaviour. Ten groups of 33 broiler breeder hens and three males were housed in two pen types: with or without a raised slatted area in front of the nests. Each pen had one plastic and one wooden nest. Between 25 and 31 weeks of age, ten marked hens per pen were weighed and assessed weekly on foot pad dermatitis, hock burn and wounds. At the end of week 31, animals were euthanized and bone strength of the tibia and humerus of these individuals was assessed. At 24, 27 and 30 weeks of age, mating behaviour was observed for an hour per pen, noting both numbers of successful and unsuccessful copulations. The number of eggs laid in the nests and on the floor was recorded daily between 20 and 31 weeks of age. Foot pad dermatitis scores were affected by age, but not by pen type. Generally, there were only minor issues with foot pad dermatitis (scores <11 on a 0–100 scale), probably due to the young age of the hens. Body weight was not affected by pen type, while the prevalence of hock burns was too low to analyse and no difference in bone strength was found for the tibia and the humerus. Overall, mating behaviour was less frequent in pens with raised slats than in pens without raised slats (29 ± 2 vs 35 ± 3 times/h) and more frequent at 27 weeks of age than at 24 and 30 weeks of age (38 ± 1 vs 31 ± 4 and 27 ± 2 times/h). The pens with raised slats had a lower percentage of floor eggs than pens without raised slats (11.2 ± 0.4 vs 19.3 ± 0.5%). The wooden nest was preferred over the plastic nest as on average 63% of the eggs were laid in the wooden nest. This study shows that providing raised slats decreases mating behaviour and percentage of floor eggs, although its effects on leg health remain inconclusive.

© 2020 The Authors. Published by Elsevier Inc. on behalf of The Animal Consortium. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

Implications

We investigated the effects of housing broiler breeders with or without a raised slatted area in front of the nests. A raised slatted area is expected to be beneficial for leg health and could function as a quiet area for females to avoid the aggressive mating behaviour of males. However, it could be difficult for hens to jump on the raised slatted area to reach the nest and this could increase the number of eggs laid outside the nest, so-called floor eggs. Floor eggs are often dirty or broken, which leads to a lower saleability and hatchability.

Introduction

The importance of housing characteristics on the welfare of broilers and laying hens has received more attention in recent years (Dawkins et al., 2004; Lay et al., 2011), but housing for broiler breeders remains a less studied topic. However, major welfare issues including aggressive mating behaviour and poor foot pad health in the broiler breeder industry have been identified (de Jong and Guémené, 2011; Kaukonen et al., 2016), which could be improved by providing the right housing. Slatted areas that are raised from the litter area and usually cover 30–50% of the house are common within European broiler breeder farms. However, in other regions of the world like the Middle East or North Africa, commercial farms often do not have large slatted areas (F. Leijten, personal communication, 13 February 2019). The presence of a raised slatted area

* Corresponding author at: Vencomatic Group, P.O. Box 160, 5520 AD Eersel, the Netherlands
E-mail address: anne.vandenoever@vencomaticgroup.com (A.C.M. van den Oever).

https://doi.org/10.1016/j.animal.2020.100109
1751-7311/© 2020 The Authors. Published by Elsevier Inc. on behalf of The Animal Consortium. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

could affect, amongst others, leg health, mating behaviour and floor laying behaviour.

Providing raised slatted areas could be beneficial for leg health by reducing the development of contact dermatitis and by increased bone loading. Foot pad dermatitis affects up to 93% of broiler breeders in a flock at slaughter age of 55–64 weeks (Kaukonen et al., 2016; van den Oever et al., 2020a). Contact dermatitis is mainly caused by contact with (moist) litter, and slatted areas give the birds an opportunity to limit the amount of time that the feet come in contact with the litter. Providing slats has therefore been suggested to benefit foot cleanliness and health (Brake, 1998), although another study found that a larger slatted area was related to poorer foot pad condition (Kaukonen et al., 2016). Both studies only investigated provision of different proportions of slatted areas and did not include the situation with no slatted area. Besides the effect on contact dermatitis, providing raised slats is also expected to increase bone strength due to loading through jumping on the raised slatted areas from the litter area and vice versa. Physical stimulation and increased load on bones have been found to be beneficial for bone strength in laying hens (Rath et al., 2000), but this relationship has not yet been investigated in broiler breeders.

Besides leg health, mating behaviour is also expected to be affected by the presence of slatted areas. Male broiler breeders show virtually no courtship behaviour, and their aggressive mating behaviour frequently leads to feather loss and wounding of the females (Millman et al., 2000; McGary et al., 2003). When raised slatted areas are provided, females often use these areas for resting, as they are rarely used by the males (de Jong and Guémené, 2011). Broiler breeder groups with a larger proportion of wounded females were found to use the slatted areas more (van den Oever et al., 2020b), suggesting that raised slatted areas might serve as a place for wounded females to avoid aggressive mating. To evaluate whether the absence of slatted areas can be considered a welfare risk, more information is needed on mating activity in housing systems with and without slatted areas.

Although raised slatted areas have the potential of improving health and welfare, it could negatively affect the number of floor eggs. Floor eggs are eggs laid outside the provided nests and are therefore often dirty and broken. This lowers their saleability and hatchability, while also requiring extra labour in the form of manual collection (van den Brand et al., 2016). Furthermore, bacterial contamination of these eggs has been identified as a critical point in salmonella infection of broiler chicks, which negatively affects their health and, moreover, also forms a public health risk (Cox et al., 2000). Hens are motivated to lay their egg in the nest that provides seclusion (Stämpfli et al., 2012), and large numbers of floor eggs could indicate problematic housing and reduced welfare. Floor laying behaviour could be caused by difficulty reaching the nest, which might be the case when the nests are only accessible via the raised slatted areas. Due to the high BW of the hens, accessing the raised slatted areas might be difficult and thereby cause more floor eggs.

This experiment aimed to study the effects of providing raised slatted areas in front of the nests on leg health, mating behaviour and floor eggs of broiler breeders by comparing two pen types: with or without a raised slatted area. Each pen was fitted with one plastic and one wooden nest to also measure the preference for nest wall material (van den Oever et al., 2020c). The prevalence of contact dermatitis, BW and bone strength were compared between pen types, as well as the frequency of mating behaviour, wounding of females and the number of floor eggs. Birds in pens with a raised slatted area were hypothesized to have less contact dermatitis, a lower BW and stronger bones compared to birds in pens without a raised slatted area. Furthermore, mating behaviour was expected to be less frequent in pens with compared to in pens without a raised slatted area resulting in fewer wounded females and we anticipated a higher percentage of floor eggs in pens with compared to pens without a slatted area. Lastly, the birds were expected to have a preference for wooden nests, expressed by a higher proportion of eggs laid in this nest than in the plastic nest.

Material and methods

Animals and housing

The study was conducted during the summer of 2019 with Ross 308 broiler breeders and was approved by the Kantonal office of Bern, Switzerland (registration number BE9/19-31068). A total of 330 females and 30 males, all non-beak trimmed, were reared with raised platforms and perches from 0 to 20 weeks of age. The birds were then relocated to 10 pens in a different room of the same barn in groups of 33 females and three males per pen balanced for BW. The pens were identical in size ($4.3 \times 2.3 \times 2.0$ m, length × width × height) and were placed in two rows. The pens had closed walls preventing visual contact. The litter area was covered with wood shavings and provided access to two feeding lines, which were partially covered with grids to create separate female and male feeding areas (20 cm per bird). The birds were given pre-lay feed (FORS Masteltern Prelay, FORS-Futter, Switzerland) for the first three weeks and lay feed (FORS Masteltern 1. Phase, FORS-Futter, Switzerland) for the remainder of the experiment. In an attempt to decrease the incidence of tail feather pecking, the feed was diluted with wheat flour pellets (Chicken-Bed, Gebr. Herzog Hornussen, Switzerland). During the last four weeks of the rearing phase and the first four weeks of the laying phase, 10% wheat flour pellets were added, and thereafter this was 5%. The litter area also provided four perches that were raised 55 and 75 cm above the litter. Half of the pens had a slatted area (1.15 m wide and 0.5 m high) from which access to five drinking nipples and two nests was given (Fig. 1A). The other half of the pens had drinkers situated in the litter area and a short ramp (0.4 m wide) that provided access to the two nests placed on the floor (Fig. 1B). The two pen types were placed alternatingly in the house to minimise location effects.

The group nests were of a rollaway type, based on commercially available nests ($1.15 \times 0.50 \times 0.50$ m, width × depth × height). All nests had a green rubber nest floor slanting towards the back and red nest curtains with an opening of 20×23 cm in the middle. Each pen had a plastic and a wooden nest, which were randomised in location across pens. The plastic nest had a dark grey back wall and black plastic side walls, while the wooden nest had a brown hardboard back wall and dark brown epoxy coated birch plywood side walls.

The house was lit with artificial LED-lighting with a photoperiod schedule according to commercial practice. At 20 weeks of age, the animals had 8 h of light (0900 to 1700 h) with a light intensity of 10 lx measured at bird height. This gradually increased with increasing age and egg productivity to 14 h of light (300 to 1700 h) with a light intensity of 19 lx at bird height at 24 weeks of age. The temperature was targeted at 19 ± 2 °C, although the temperature rose to a maximum of 30 °C on warm days despite the cooling efforts of a mist ventilator. Feed was provided at lights-on and given in a restricted amount according to the guidelines of the breeding company (Aviagen, 2018). At 20 weeks of age, the animals received 98 g per individual per day, which was gradually increased to 152 g per individual per day with age and egg productivity. Random samples of five birds per pen were weighed weekly to ensure optimal body condition and flock uniformity. Water was provided ad libitum. The nests were available to the hens from 15 min before lights-on until 15 min before lights-off, from the day after the first egg was found (23 weeks of age) until the end of the experiment. The experiment was terminated when the birds were 32 weeks of age after which the birds were re-used in a second, unrelated study.

Data collection

In each pen, 10 hens were marked with a backpack for individual recognition. Starting at 25 weeks of age until the end of the experiment, health assessments were performed weekly on all focal birds. The focal birds were weighed and scored for: foot pad dermatitis (left and right leg separately), hock burns (left and right leg separately) and wounds



Fig. 1. Photos of the pen types for housing the broiler breeders. A) Pen with nests placed on the raised slatted area. B) Pen with nests placed in the litter with a short ramp for nest access.

on the back and rump using visual analogue scales ranging from 0 to 100 based on a combination of the Welfare Quality® protocol for poultry (Welfare Quality®, 2009) and the MTool© (Keppler and Knierim, 2017). The visual analogue scales are included as Supplementary Materials S1–3. Scoring was done by two observers, and 20 hens were scored by both observers to assess interobserver reliability. An intraclass correlation coefficient was calculated using a two-way mixed model based on consistency and average measures (Koo and Li, 2016). We found a good agreement for wounds (0.769; 95% CI 0.564–0.878; $F_{39,39} = 4.336$, $P < 0.0001$) and the right foot pad dermatitis score (0.748; 95 CI 0.524–0.867; $F_{39,39} = 3.969$, $P < 0.0001$), while the agreement was excellent for the left foot pad dermatitis score (0.927; 95% CI 0.862–0.962; $F_{39,39} = 13.744$, $P < 0.0001$). Hock burns were not observed in the test hens. The focal birds were euthanized to collect the tibia and humerus at the end of the experiment. The strength of these bones was then measured at 15 °C using the three-point bending test as described in the ANSI/ASAE S459 MAR1992 (R2007) standard with some modifications as published by Gebhardt-Henrich et al. (2017a) using a Zwick and Roell universal testing machine with a 2.5 kN load cell.

Live observations on mating behaviour of the males were done at 24/25, 27/28 and 30/31 weeks of age, observing one pen with raised slats and one pen without raised slats per day between 1400 and 1600 h and thus observing all 10 pens in one week. Pen types were observed alternatingly for 2 × 30 min per pen with two observers, each observing one or two males to record the behaviour of all three males per pen. Frequencies of behaviours as listed in Table 1 were recorded continuously. Interobserver reliability was evaluated by doing two trial sessions of 20 min previous to the official observations, which resulted in full agreement on the frequency of the scored behaviours.

Eggs were collected separately from each nest and from other areas of the pen with the latter noted as floor eggs. Eggs were collected three times a day, seven days a week between 0730 and 1630 h. Egg collection started with the first egg at the age of 23 weeks and continued until the experiment was terminated at 31 weeks of age.

Statistical analysis

The maximum foot pad score of either the left or the right leg was used for analysis. Hock burns scores and wounds scores were not analysed, as pen type averages at all ages were lower than 1 (on a 0–100 scale). Mating behaviour observations of 2 × 30 min were summed as frequencies per hour. Chasing behaviour was not analysed due to low incidence. Frequencies of mounting attempts and copulations were summed to calculate total mating activity, while mating success was calculated by dividing the number of copulations by the total mating activity. The percentage of eggs laid in the wooden nest was calculated by dividing the number of eggs laid in the wooden nest by the total number of eggs laid in both nests. The production percentage per pen was calculated by dividing the total number of eggs laid by the number of hens present in the pen. Production percentage was averaged per week for analysis. The floor egg percentage per pen was calculated by dividing the number of floor eggs by the total number of eggs.

All statistical analyses were performed with SAS (version 9.4). *P*-values below 0.05 were considered significant and the pairwise comparisons following significant results were performed with the Tukey

Table 1
Ethogram of mating behaviours recorded as frequencies during continuous observations of broiler breeder males during 2 × 30 min per pen per age (24/25, 27/28 and 30/31 weeks of age).

Behaviour	Description
Mating attempt	The male approaches a female and places one or both feet on her back. The female avoids the male, and no further elements of the copulatory sequence are observed.
Copulation	The male mounts, grips and treads a female and appears to achieve cloacal contact. The female ruffles her feathers following the male's dismount.
Chasing	The male runs at a female, with or without wings raised.

method. To test for a preference for nest design, the proportion of eggs in wooden nests was analysed using the GENMOD procedure to perform a logistic regression model, which included pen as a repeated subject in which the autoregressive covariance structure AR(10) fitted best. To test for an effect of pen type, age and their interaction, the mating behaviour (number of attempts and copulations) was analysed using the GENMOD procedure to perform a negative binomial regression model, including the Wald test for type 3 effects and pen as a repeated subject with an exchangeable correlation structure. The success of mating was analysed with GENMOD with a binary distribution. The percentage of floor eggs (from the total of eggs) was analysed using logistic regression with height, age and their interaction in the model (PROC GENMOD). The egg production, BW and bone strength were analysed using the MIXED procedure to perform general linear mixed models. As fixed effects pen type, week of age and its interaction were included, while age was included as a repeated effect with pen as subject. Since the relative bone strength was only measured at one time point, age was not included as a fixed or repeated effect. Foot pad dermatitis was analysed using the GLIMMIX procedure to perform a generalized linear mixed model with a multinomial distribution and cumulative logit link function. As fixed effects pen type, week of age and its interaction were included, while pen within pen type was included as a random effect. The assumptions of homogeneity of variance and normally distributed errors were examined visually using the conditional studentized residuals plots. The CORR procedure was used to calculate Pearson's correlations between frequency of mating behaviour and percentage of floor eggs. Results are shown as non-transformed means with the corresponding standard error of means.

Results

Foot pad dermatitis scores were low during the experiment, as the highest average score per pen type was less than 11 on a scale from 0 to 100. The foot pad dermatitis score had a tendency to be affected by the interaction between pen type and age ($F_{6,635} = 1.7$, $P = 0.085$) and was significantly affected by age ($F_{6,635} = 10.5$, $P < 0.0001$), see Fig. 2. At 27 weeks of age, the hens had a higher foot pad dermatitis score compared to 25 and 29–31 weeks of age, while at the ages of 26 and 28 weeks the hens had an intermediate foot pad dermatitis score. No difference was seen between pen types during all ages. Body weight of the hens steadily increased with age ($F_{6,580} = 71.4$, $P < 0.0001$) from 3 245 ± 23 g at 25 weeks of age to 3 659 ± 23 g at 31 weeks of age with no differences between the pen types. Hock burns were barely observed, resulting in average scores per pen type of less than 1 (on a 0–100 scale) at all ages. The bone strength of both the tibia and humerus did not differ between the pen types. Tibia strength was on average 199.1 ± 8.6 N for the pens with raised slats and 195.9 ± 8.4 N for the pens without raised slats at the point of failure. Humerus strength was on average 386.4 ± 18.6 N for the pens with raised slats and 387.8 ± 19.5 N for the pens without raised slats at the point of failure.

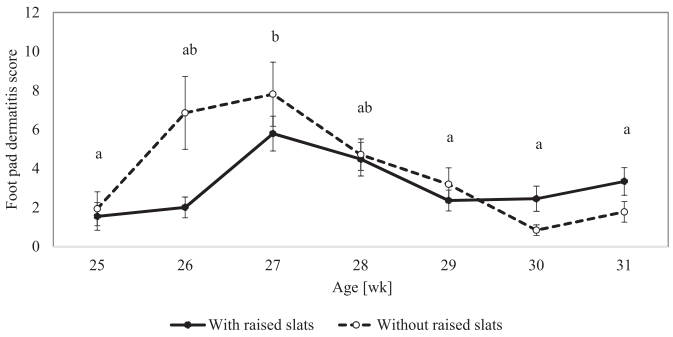


Fig. 2. Foot pad dermatitis score per week of age based on 10 broiler breeder hens per pen, specified for pens with ($n = 5$) and without raised slats ($n = 5$). Error bars depict SEM, letters indicate significant differences between weeks of age ($P < 0.05$).

The results regarding the mating behaviour are depicted in Fig. 3. Total mating activity (copulations + mating attempts) was higher at 27 weeks of age compared to 24 and 30 weeks of age ($P < 0.0001$), while the pens without raised slats had more mating activity than pens with raised slats ($P = 0.0414$). For the number of mating attempts the interaction between age and pen type was significant ($P = 0.0218$). At 24 weeks of age the males in the pens without raised slats had almost twice as many attempts compared to the males in pens with raised slats (20.0 vs 10.6 attempts per hour). The frequency of mating attempts did not differ between the pen types at the later ages. The number of copulations was affected by age ($P < 0.0001$), but not by pen type. At 27 weeks of age three males copulated on average 23.0 times per hour, compared to 15.5 and 16.4 copulations per hour at 24 and 32 weeks of age. Males had lower mating success at 24 weeks of age with 52.2 ± 2.6% compared to 27 and 30 weeks of age with, respectively, 61.1 ± 3.3% and 59.8 ± 2.6% ($P = 0.015$) with no differences between the pen types. Hardly any wounds were observed on the hens, resulting in average wound scores of less than 1 (on a 0–100 scale) for each pen type.

During the experiment 10 574 eggs were laid in the nests and 1 893 eggs were laid on the floor (15.2% floor eggs). Egg production increased with age ($F_{9,64} = 1016.4$, $P < 0.0001$) without any differences between pen types. Floor egg percentage was, however, affected by pen type ($P < 0.0001$) with fewer floor eggs in the pens with raised slats (11.2 ± 0.4%) than in pens without raised slats (19.3 ± 0.5%). The percentage of floor eggs was not correlated to the frequency of mating attempts, copulations, total mating activity or mating success.

The percentage of eggs laid in the wooden nest (63.1 ± 0.5%) was higher than that laid in the plastic nests (36.9%). Corrected for the random pen effect, the probability that eggs are laid in a wooden nest is 63.4% (95% CI: 53.0–72.6) and thus significantly higher than 50% expected if the birds would have no preference ($P = 0.0118$). The pens, however, varied highly in the percentage of eggs laid in the wooden nests, with two pens laying fewer eggs in the wooden nest than in the plastic nest, and one pen laying exactly 50% of their eggs in each of the nests (Fig. 4). The percentage of eggs laid in the wooden nests was not affected by age or pen type.

Discussion

Leg health

Contact dermatitis on both foot pads and hocks was hardly observed and no differences were found between average scores of foot pad dermatitis in hens kept in pens with a slatted area compared to hens kept in pens without slatted areas. The provision of a slatted area was expected to be beneficial for foot pad health, since contact with (moist) litter is the main cause for developing foot pad dermatitis (Martland, 1985) and providing slatted areas gives hens an opportunity to limit their contact with the litter. The effect of the slatted area on contact dermatitis, as well as the later discussed of BW and bone strength, could have been diminished by the provision of perches in all pens. Although no regular and objective observations were performed, a large proportion of the hens used the perches, which is in line with earlier studies on perch use in broiler breeders (Gebhardt-Henrich et al., 2017b). Perches are still uncommon in commercial housing for broiler breeders, although an increasing number of European countries have included perches as a minimum housing requirement for broilers breeders. Another possible reason for not finding consistent beneficial effects of a raised slatted area on contact dermatitis is that the hens were too young to develop foot pad problems. Foot pad dermatitis generally increases with age, so we might have found more differences in foot pad health if the experiment was terminated at a later age (Kaukonen et al., 2016; van den

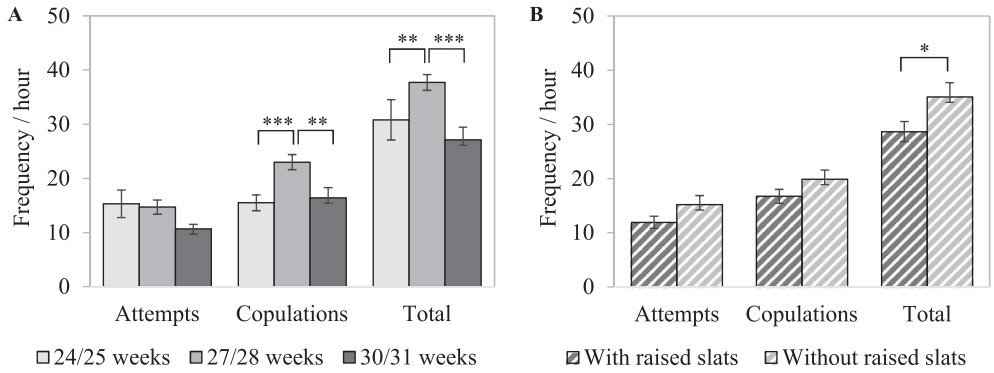


Fig. 3. Average frequencies of mating attempts, copulations and total mating activity performed by 3 broiler breeder males per pen specified per age (A) and pen type (B). Effects of age are based on 10 pens and each pen type was replicated 5 times. Asterisks indicate significant differences ($^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$).

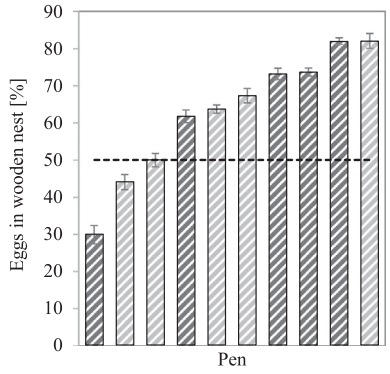


Fig. 4. The percentage of eggs laid in the wooden nests by the broiler breeder hens, specified per pen based on daily measurements of number of eggs laid in the wooden and plastic nest provided in each pen (total 59 days). The dark bars depict pens with raised slats ($n = 5$), the light bars depict pens without raised slats ($n = 5$). The dotted line depicts 50% of eggs.

Oever et al., 2020a). Hock burns were observed with such rarity that they could not be analysed. This low occurrence of hock burns is probably also partially due to the young age of the hens, but hock burns seem to have a low prevalence in broiler breeders at all ages with less than 1% of the hens affected by severe hock burns (Kaukonen et al., 2016; van den Oever et al., 2020a).

Also against expectations, we did not find an effect of providing raised slats on the bone strength of both the tibia and humerus. Our hypothesis was based on previous studies with laying hens, which show that more complex housing systems, including multi-tier aviaries or extra perches, are beneficial for the bone strength at the end of the production period (Fleming et al., 1994; Wilkins et al., 2011). However, in a previous study with broilers, placing barriers between the feeder and drinker did not have an effect on bone strength at the slaughter age of 42 days (Bizeray et al., 2002). The lack of an effect of raised structures on bone strength in the broiler study as well as our current study could be explained by a shorter exposure time. It could also be due to a lower responsiveness of bones to mechanical loading in broiler breeders, as has been established in broilers compared to laying hens (Pitsillides et al., 1999).

The BW of the hens increased steadily with age, but without any differences between pen types. This is not in line with our expectations, as we hypothesized that the raised slatted areas would result in a lower BW due to the extra energy expenditure of jumping on and off the raised slatted area, while the hens were not able to increase their feed intake due to feed restriction. The birds housed with raised slatted areas could have compensated for the jumping by having a lower activity level during the rest of the day and therefore not increasing their total energy expenditure.

Mating behaviour

As expected, more mating behaviour was observed in the pens without a slatted area than in the pens with a slatted area. Mating behaviour generally takes place in the litter (de Jong and Guémené, 2011), so a larger litter area allows for more mating behaviour. The mating behaviour was also affected by age, as the males were most active at 27 weeks of age and less active at 24 and 30 weeks of age. At 24 weeks of age, the males are still inexperienced and a large number of females are not mature enough yet, explaining the low mating activity and low mating success (= successful copulations divided by total mating activity). Furthermore, it is known that the mating activity of broiler breeder males decreases with age (Duncan et al., 1990; McGary et al., 2003), and an earlier study described the peak of mating behaviour to be at 28 weeks of age in two strains of broiler breeders (Moyle et al., 2010) which is supported by our findings.

Although the mating activity differed between pen types, the frequency of successful copulations was not lower in pens with a raised slatted area compared to pens without this area. This absence of a difference in copulation frequency suggests that the fertilisation of the eggs is probably not influenced by the provision of a raised slatted area. The slatted area can therefore increase hen welfare by lowering the general mating activity and providing an opportunity for hens to avoid mating, likely without compromising the fertility rate that forms the basis of the farmers' income. As a measure of the effect of mating on the hens' welfare, the prevalence of wounds was monitored during the course of the experiment. Wounds were observed so little on the hens that it could not be analysed. A previous study on broiler breeders showed that the majority of wounding in females happens later in the production cycle, which was at least partially due to a poor feather coverage (van den Oever et al., 2020b). So while we did find a difference in mating frequency between the pen types, it remains unsure whether this affects the prevalence of wounds at a later age.

Floor eggs

The percentage of floor eggs was much higher during this experiment (7–26%) compared to the 6% found in our previous experiment on nest design preference (van den Oever et al., 2020c), which can be explained by a number of factors. First, the pens in the current experiment were half as wide as the pens in the previous experiment. Smaller-sized pens appear to be more inviting for floor laying behaviour, since there are relatively more sheltered areas against walls and fewer open spaces than in wider pens. Chickens tend to look for a

sheltered space to lay their egg as this provides a sense of safety and less chances for disturbance (Duncan and Kite, 1989). Second, the light intensity was kept at 19 lx during the experiment to prevent further development of gentle feather pecking behaviour directed at the tails that had started in the rearing phase. The light intensity was chosen so that the behaviour did not worsen (Kjaer and Vestergaard, 1999) while also providing more than 10 lx of photostimulation needed for normal egg production (Lewis et al., 2008). Although the chosen light intensity was successful in terms of these two goals, it is lower than the recommended 30–60 lx to prevent creating dark areas that are preferred for floor laying (Aviagen, 2018). A third explanation can be found in the group size. Small groups of chickens allow for individual recognition and the establishment of a dominance hierarchy, while in larger groups a system of social tolerance is maintained (D'Eath and Keeling, 2003). The previous experiment had groups of 100 hens, which is considered large for chickens (Nicol et al., 1999) while the groups of 33 hens in this experiment could be problematic. When comparing groups of 15, 30, 60 and 120 laying hens, the groups of 30 had a lower BW and egg production than the smaller or larger groups (Keeling et al., 2003). It was proposed that this 'intermediate' group size creates social disruption around key resources like the nest area which could increase the number of floor eggs. Furthermore, the willingness of a hen to defend or compete for a nest is thought to be higher in smaller groups compared to larger groups, which is also expected to affect the percentage of floor eggs (Estevez et al., 2007).

Surprisingly, the pens with raised slatted areas had a lower percentage of floor eggs than the pens with the nest directly placed on the litter. The fact that hens needed to jump onto the raised slatted area to reach the nest was apparently not a limiting factor for laying the eggs in the nest. It is possible that the hens were simply too young, and therefore mobile, to be burdened by the jump. It is also possible that the motivation to reach the nest is larger than the effort of jumping. A previous study of broiler breeders housed with raised slatted areas found that deteriorating leg health with age was not related to an increase in floor eggs, suggesting that mobility is not the most important factor involved in floor laying behaviour (van den Oever et al., 2020a). Most floor eggs are laid in the litter and not on structures such as slatted areas. This could explain why the pens without slats, and therefore with a larger litter area, had a higher percentage of floor eggs. Furthermore, as mentioned before, males tend to avoid spending time on the slatted area, which means that the males probably spend less time near the nests in the pens with a raised slatted area. Hens in the nest likely experience less disturbance of males in front of the nest, which could also increase the number of eggs laid in the nest.

Preference nest design

The preference for wooden nests found in this study is in agreement with the findings of our previous preference test on nest design (van den Oever et al., 2020c). However, the proportion of eggs laid in the wooden nest was slightly lower with 63% in this study compared to 69% in our previous study. The current study also showed more variation between pens regarding their preference for nest design. In two out of ten pens, fewer eggs were laid in the wooden nest than in the plastic one, and in one pen the eggs were divided equally over each of the nests. This slightly lower and less consistent preference for the wooden nest compared to the previous study could be explained by some design differences, namely shape, material and colour. The nests in the current experiment had a curved back wall instead of straight, as this was standard for the commercial nest used in this study. The material used for the walls in the previous experiment could not be curved and was therefore replaced by a softer type of wood. This type of wood has no coating, making the surface more rough and perhaps slightly less attractive for the hens. The plastic nests in the current experiment had dark grey coloured walls, while these were black in the previous experiment. As the reasons behind the preference for wooden materials remains unknown, it cannot be ruled out that shape, type of wood or colour influence nest design preference.

Conclusion

This study shows that providing raised slatted areas to broiler breeders positively affects their behaviour, but the consequences for their leg health remain unclear. The frequency of mating behaviour was lower in groups with a raised slatted area, which suggests that this is beneficial for the welfare of the hens as mating is known to be aggressive in broiler breeders. The percentage of floor eggs was lower as well in groups with raised slats, meaning more hens laid their eggs in a secluded nest as they are intrinsically motivated to do. We did not find the expected beneficial effects of a raised slatted area on leg health, but this was likely due to their young age or the provision of perches and should be investigated in a longer running experiment in the future.

Supplementary materials

Supplementary data to this article can be found online at https://doi.org/10.1016/j.animal.2020.100109.

Ethics approval

This study was approved by the Veterinary Office of the Canton of of Bern, Switzerland (registration number BE9/19-31068).

Data and model availability statement

The data that support the findings of this study are available upon request from the authors. None of the data were deposited in an official repository.

Author ORCIDs

Anna C.M. van den Oever (corresponding author): 0000-0002-4274-8856.
Laura Candelotto: /.
Bas Kemp: 0000-0002-9765-9105.
T. Bas Rodenburg: 0000-0002-3371-1461.
J. Elizabeth Bolhuis: 0000-0002-5172-7635.
Elisabeth A.M. Graat: /.
Lotte J.F. van de Ven: /.
Dominik Guggisberg: /.
Michael J. Toscano: 0000-0001-8185-3002.

Author contributions

Anna C.M. van den Oever (corresponding author): Conceptualization, methodology, formal analysis, investigation, writing – original draft, project administration. Laura Candelotto: Conceptualization, methodology, formal analysis, investigation, writing – review & editing, project administration. Bas Kemp: Conceptualization, writing – review & editing. T. Bas Rodenburg: Conceptualization, writing – review & editing. J. Elizabeth Bolhuis: Conceptualization, writing – review & editing. Elisabeth A.M. Graat: Methodology, formal analysis, writing – review & editing. Lotte J.F. van de Ven: Conceptualization, resources, writing – review & editing. Dominik Guggisberg: Methodology, investigation, resources, writing – review & editing. Michael J. Toscano: Conceptualization, methodology, resources, writing – review & editing, supervision.

Declaration of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Acknowledgements

The authors thank Markus Schwab, Abdulsatar Abdel Rahman (Center for Proper Housing of Poultry and Rabbits) and Ronald Bax (Vencomatic Group BV) for their technical assistance, Camille Raoult for her practical help and the Aviforum team for taking care of the animals.

Financial support statement

This work was supported by Vencomatic Group, Eersel, the Netherlands, and by the Swiss Federal Food Safety and Veterinary Office FSVO (grant number 2.19.02).

References

Aviagen, 2018. Ross PS management handbook 2018. Retrieved on 4 April 2020 from http://en.aviagen.com/brands/ross/products/ross-308.
Bizeray, D., Estevez, I., Leterrier, C., Faure, J.M., 2002. Influence of increased environmental complexity on leg condition, performance, and level of fearfulness in broilers. Poultry Science 81, 767–773.
Brake, J., 1998. Equipment design for breeding flocks. Poultry Science 77, 1833–1841.
Cox, N.A., Berrang, M.E., Cason, J.A., 2000. Salmonella penetration of egg shells and proliferation in broiler hatching eggs – a review. Poultry Science 79, 1571–1574.
Dawkins, M.S., Donnelly, C.A., Jones, T.A., 2004. Chicken welfare is influenced more by housing conditions than by stocking density. Nature 427, 342–344.
de Jong, I.C., Guémené, D., 2011. Major welfare issues in broiler breeders. World's Poultry Science Journal 67, 73–82.
D'Eath, R.B., Keeling, L.J., 2003. Social discrimination and aggression by laying hens in large groups: from peck orders to social tolerance. Applied Animal Behaviour Science 84, 197–212.
Duncan, I.J.H., Kite, V.G., 1989. Nest site selection and nest-building behaviour in domestic fowl. Animal Behaviour 37, 215–231.
Duncan, I.J.H., Hocking, P.M., Seawright, E., 1990. Sexual behaviour and fertility in broiler breeder domestic fowl. Applied Animal Behaviour Science 26, 201–213.
Estevez, I., Andersen, I.L., Nævdal, E., 2007. Group size, density and social dynamics in farm animals. Applied Animal Behaviour Science 103, 185–204.
Fleming, R.H., Whitehead, C.C., Alvey, D., Gregory, N.G., Wilkins, L.J., Whitehead, C.C., Alvey, D., Gregory, N.G., Wilkins, L.J., 1994. Bone structure and breaking strength in laying hens housed in different husbandry systems. British Poultry Science 35, 651–662.
Gebhardt-Henrich, S.G., Pfulg, A., Fröhlich, E.K.F., Käppeli, S., Guggisberg, D., Liesegang, A., Stoffel, M.H., 2017a. Limited associations between keel bone damage and bone properties measured with computer tomography, three-point bending test, and analysis of minerals in Swiss laying hens. Frontiers in Veterinary Science 4, 128.
Gebhardt-Henrich, S.G., Toscano, M.J., Würbel, H., 2017. Perch use by broiler breeders and its implication on health and production. Poultry Science 96, 3539–3549.
Kaukonen, E., Norring, M., Valros, A., 2016. Effect of litter quality on foot pad dermatitis, hock burns and breast blisters in broiler breeders during the production period. Avian Pathology 9457, 1–15.
Keeling, L.J., Estevez, I., Newberry, R.C., Correia, M.G., 2003. Production-related traits of layers reared in different sized flocks: the concept of problematic intermediate group sizes. Poultry Science 82, 1393–1396.
Keppler, C., Knierim, U., 2017. MTool managementtool © – Beurteilungskarten Legehennen. Retrieved on 7 May 2020 from https://www.mud-tierschutz.de/mud-tierschutz/beratungsinitiativen/etablierung-eines-managementtools-bei-legehennen/mtool-fuer-jung-und-legehennen/.
Kjaer, J.B., Vestergaard, K.S., 1999. Development of feather pecking in relation to light intensity. Applied Animal Behaviour Science 62, 243–254.
Koo, T.K., Li, M.Y., 2016. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. Journal of Chiropractic Medicine 15, 155–163.
Lay, D.C., Fulton, R.M., Hester, P.Y., Karcher, D.M., Kjaer, J.B., Mench, J.A., Mullens, B.A., Newberry, R.C., Nicol, C.J., O'Sullivan, N.P., Porter, R.E., 2011. Hen welfare in different housing systems. Poultry Science 90, 278–294.
Lewis, P.D., Danisman, R., Gous, R.M., 2008. Illuminance, sexual maturation, and early egg production in female broiler breeders. British Poultry Science 49, 649–653.
Martland, M.F., 1985. Ulcerative dermatitis in broiler chickens: the effects of wet litter. Avian Pathology 14, 353–364.
McGary, S., Estevez, I., Russek-Cohen, E., 2003. Reproductive and aggressive behavior in male broiler breeders with varying fertility levels. Applied Animal Behaviour Science 82, 29–44.
Millman, S.T., Duncan, I.J., Widowski, T.M., 2000. Male broiler breeder fowl display high levels of aggression toward females. Poultry Science 79, 1233–1241.
Moyle, J.R., Yoho, D.E., Harper, R.S., Bramwell, R.K., 2010. Mating behavior in commercial broiler breeders: female effects. Journal of Applied Poultry Research 19, 24–29.
Nicol, C.J., Gregory, N.G., Knowles, T.G., Parkman, I.D., Wilkins, L.J., 1999. Differential effects of increased stocking density, mediated by increased flock size, on feather pecking and aggression in laying hens. Applied Animal Behaviour Science 65, 137–152.
Pitsillides, A.A., Rawlinson, S.C.F., Mosley, J.R., Lanyon, L.E., 1999. Bone's early responses to mechanical loading differ in distinct genetic strains of chick: selection for enhanced growth reduces skeletal adaptability. Journal of Bone and Mineral Research 14, 980–987.
Rath, N.C., Huff, G.R., Huff, W.E., Balog, J.M., 2000. Factors regulating bone maturity and strength in poultry. Poultry Science 79, 1024–1032.
Stämpfli, K., Buchwalder, T., Fröhlich, E.K.F., Roth, B.A., 2012. Influence of front curtain design on nest choice by laying hens. British Poultry Science 53, 553–560.
van den Brand, H., Sosef, M.P., Lourens, A., van Harn, J., 2016. Effects of floor eggs on hatchability and later life performance in broiler chickens. Poultry Science 95, 1025–1032.
van den Oever, A.C.M., Bolhuis, J.E., van de Ven, L.J.F., Kemp, B., Rodenburg, T.B., 2020a. High levels of contact dermatitis and decreased mobility in broiler breeders, but neither have a relationship with floor eggs. Poultry Science 99, 3355–3362.
van den Oever, A.C.M., Kemp, B., Rodenburg, T.B., van de Ven, L.J.F., Bolhuis, J.E., 2020b. Gregarious nesting in relation to floor eggs in broiler breeders. Animal.
van den Oever, A.C.M., Rodenburg, T.B., Bolhuis, J.E., van de Ven, L.J.F., Hasan, M.K., van Aerle, S.M.W., Kemp, B., 2020c. Relative preference for wooden nests affects nesting behaviour of broiler breeders. Applied Animal Behaviour Science 222, 104883.
Welfare Quality®, 2009. Welfare quality® assessment protocol for poultry (broilers, laying hens). Welfare Quality® Consortium, Lelystad, The Netherlands.
Wilkins, L.J., McKinstry, J.L., Avery, N.C., Knowles, T.G., Brown, S.N., Tarlton, J., Nicol, C.J., 2011. Papers: influence of housing system and design on bone strength and keel bone fractures in laying hens. The Veterinary Record 169, 414.