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Perch shape and material affect perch use and health parameters of laying hens during the rearing and laying phase

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Primary Audience: Researchers, Plant Managers

SUMMARY

Perches are an important resource for laying hens and differ in characteristics like shape, material and diameter. In this study, different perches were tested in regard to animal welfare, focusing specifically on the behavior and health of laying hens during rearing and lay. Five perches, i.e., square-fiber, mushroom-metal, mushroom-plastic, round-plastic and round-metal perches, were installed in 15 experimental pens with 1 perch type per pen. Each pen was populated with 20 hens (10 Lohmann Selected Leghorn and 10 Lohmann Brown hens) and kept in the same pen from d 1 until 40 wk of age. Different behaviors and health parameters (i.e., keel, footpad and plumage condition) were assessed at various ages by scan sampling and continuous observations of video recordings and live assessments, respectively. Perch use was affected by age, hybrid and perch type: it increased with age, white birds used perches more than brown birds, the round-metal perch was used the least and the mushroom-metal perch the most. In more than 50% of observed walking bouts on perches, balance movements occurred. These were observed more during the dusk phase and on the mushroom-shaped perches while birds with the round-metal perch had the least balance problems but also the least number of walking bouts. All health parameters were of minor severity. They were however influenced by perch type and age, where all of them increased with age and in birds with mushroom-metal perches. Hen behavior and health were affected by perch type, highlighting its significance for laying hen welfare.

Key words: poultry welfare, authorization procedure, behavior

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DESPRIPTION OF THE PROBLEM

Perches are an important resource for laying hens and thus are required by law in some countries (e.g., Switzerland: TSchV, 2022; EU Council Directive, 1999). Perching behavior stems from the red jungle fowl, the ancestor of the domestic chicken and serves to protect birds from night-time ground predation (see overview by Nicol (2015)). Domestic laying hens still have the behavioral need to perch, show signs of distress when access to perches is denied (Olsson and Keeling, 2002) and are

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willing to work in order to get access to them (Olsson and Keeling, 2000). Research on perch characteristics for laying hens has been conducted for many years and a good summary on the subject is provided by the EFSA (2005, 2015). In commercial settings, welfare-friendly housing systems for laying hens, such as aviary systems and other noncage systems, typically incorporate round metal perches, which serve a dual purpose of providing perching space for the birds and structural support for the housing system. Other types of perches with varying characteristics specifically aiming to cater to the behavior of the hens are also commercially available but are not used often.

In order for the birds to use perches during the laying phase, providing pullets with perches during the rearing phase is crucial as they will not learn to use them properly otherwise (Gunnarsson et al., 2000). The few studies on perches conducted during the rearing phase have mainly focused on the age chicks start using perches and how this affects their development and their use of perches later during lay. For example, it was shown that chicks start perching from 1 wk of age onwards (Heikkilä et al., 2006, Wichman et al., 2007) and that this behavior increases with age (Liu et al., 2018). Studies on chicks' preference for perch type are limited but Skånberg et al., (2021) showed that perch diameter and shape both influenced perch use and balance movements. More specifically, a wider perch surface was considered beneficial compared to a narrower 1 in terms of safe landings and perch use. This was especially the case during the first wk of age when chicks started perching.

Studies on perch characteristics such as material, width and shape have shown effects on the hens' preferences and behavior (see review by Struelens and Tuyttens, 2009 and more recently, Bist et al., 2023). In terms of effects of perch material, results are ambiguous with hens showing no clear preference between wood, plastic and metal in some studies (e.g., Lambe and Scott, 1998, review see Bist et al., 2023). However, Gebhardt and Fröhlich (2010) did find round metal perches to be avoided by laying hens when they had the choice. A more comprehensive study on the effects of perch diameter and material on behavior was conducted by Pickel et al. (2010) who found that balance problems decreased with increasing diameter and occurred more while walking on round metal perches compared to other perch material, e.g., cushioned or wooden perches. The authors suggested that certain perch materials increase the slipperiness of perches and thus would lead to more balance problems. This point was discussed in other studies as well (e.g., Scott and MacAngus, 2004; Struelens and Tuyttens, 2009). In these studies, evidence was provided that a variety of bird behaviors, such as standing and posture during resting, were affected by the perch material provided.

In terms of influences of perch type on laying hen health, studies have mostly been focusing on keel bone and footpad health as these 2 body parts are in contact with the perch the most. In fact, the pressure on the keel bone during perching is 5 times higher compared to the foot pads (Pickel et al., 2011), which is why the keel bone is very prone to be affected by different perch materials and shapes. A study investigating this relationship found that rubber-coated metal perches were negatively associated with the occurrence of keel bone damage when compared to plastic perches (Käppeli et al., 2011). Regarding shape, material and diameter, it was shown that round perches and perches with a small diameter were associated with more keel bone damage such as fractures and deviations compared to rectangular perches (Tauson and Abrahamsson, 1996). Additionally, the number of keel bone fractures was lower in round cushioned perches compared to round metal perches (Stratmann et al., 2015a) and perches with a larger diameter (Niebuhr et al., 2008). Concerning footpad lesions, mushroom-shaped perches have been shown to be positively associated with such lesions compared to other shapes (Oester, 1994; Tauson and Abrahamsson, 1996). And in terms of material, plastic perches were more associated with footpad lesions than wooden perches (Valkonen et al., 2005). More recent studies on effects of perch characteristics on bird health is lacking and none whatsoever have been conducted in pullets. According to the authors' knowledge, plumage condition was never investigated in the context of different perch designs so far.

When studying perch characteristics and preferences, 1 important fact to consider is that the height of the perch is always more important for the birds than the perch type itself (i.e., material, shape, diameter, etc.) (Schrader and Müller, 2009, Brendler et al., 2014). Therefore, to investigate the impacts of perch type on health and behavior, the same perch type should be provided at various heights, giving access to only 1 perch type per experimental group at a given time. In the present study, 5 perches differing in material, shape and diameter were examined to assess their suitability in terms of behavior and health. All perches were commercially available for rearing and laying systems in Switzerland and the aim was to examine the perches in terms of animal welfare within the framework of the FSVO's authorization procedure (Art. 7, Para 2 TSchG, Art. 81, 82 TSchV, concept overview see Wechsler, 2005). To do so, the behavior (i.e., use of perches, walking on and transitioning between perches and balance movements) was assessed during the rearing and laying phase and bird health (i.e., keel bone health, footpad health and plumage condition) was assessed on focal level during the laying phase. Based on the existing literature, we assumed that the type of perch would have varying impacts on behavior and health. We predicted that the round metal perch would fare worse than the other perches but did not have clear predictions for differences between the other perch types.

MATERIALS AND METHODS

Ethical Note

Approval to conduct the study was obtained from the Veterinary Office of the Canton Bern in Switzerland (approval number BE27/19). The experiment complied with the Swiss regulations regarding the treatment of experimental animals.

Animals and Housing

The study was conducted at the Centre for proper housing of poultry and rabbits (ZTHZ) in Zollikofen, Switzerland in an on-site experimental barn, which was equipped with 15 pens in 4 rows, each holding 20 birds (N= 300 birds in total). Of these 20 birds, 10 birds were of a white layer line (LSL = Lohmann Selected Leghorn) and the other 10 birds were of a brown layer line (LB = Lohmann Brown). Birds were populated as 1-day-old chicks and kept in the same pen during the rearing and laying phase until 40 wk of age (woa). The rearing phase was defined from 1 d of age until the end of 17 woa whereas the laying phase was defined from 18 woa until the end of the study at 40 woa. Each pen (size: 300 × 370 cm) was equipped with a raised grid area (size: 115 × 140 cm), a round feeder, 5 nipple drinkers as well as a raised group nest (Vencomatic Classic, Vencomatic Group, Netherlands). Each pen was equipped with 2 perches that were placed above the grid area at 2 different heights (1st perch: 50 cm from the grid area and 2nd perch: 80 cm from grid area with 30 cm of horizontal distance between the perches) providing 14 cm perch space per adult hen, which is compliant with the Animal Welfare Ordinance of Switzerland (Anh.1, Tab. 9-1, TSchV). The whole pen floor was covered with an approximately 5 cm deep litter of wood shavings which was kept dry throughout the experiment by adding wood shavings when necessary. Air quality was standardized by having an air vent in each pen. The light schedule during rearing and laying was programmed according to the standard management guidelines recommended for LSL hybrids by Lohmann (Lohmann Management Guide, 2024). Chicks had 24 h of light for the first 2 d after which the light was gradually decreased to a minimum of 8 h from 6 to 16 woa and then gradually increased again to a maximum of 15 h at woa 24. A dusk phase of 30 min in the evening was provided. Day light was not provided during both phases and a standard diet for pullets and layers was provided ad libitum (Kunz Kunath AG, Burgdorf, Switzerland). During the first 9 d after population, chicks were confined in a smaller part of the litter area to ease access to feed and water, which were provided using a bell drinker and a feeding plate per pen. After 9 d chicks got access to the whole litter area and after 14 d access to the raised grid area was given using a ramp. The 2 perches per pen were initially positioned at

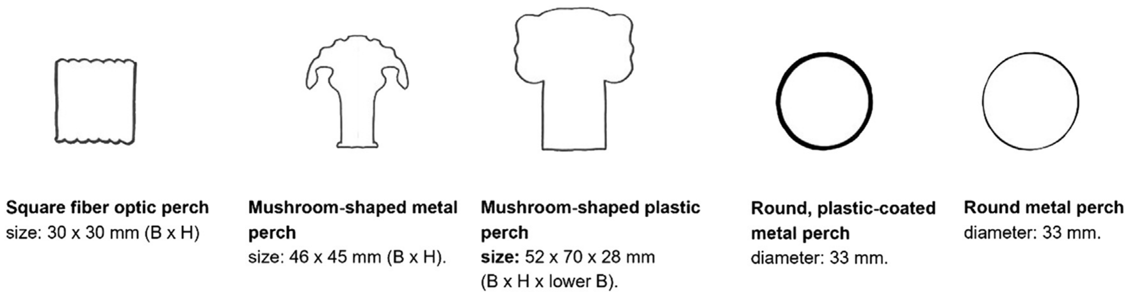

Figure 1. Cross sections of the 5 different perches used in the experiment. The first 2 perches (square-fiber and mushroom-metal perches) were newer types while the last 3 were already commonly used in pullets and layer houses in Switzerland.

heights of 10 cm and 30 cm above the grid surface and adjusted to the size of the birds with increasing the heights to 30 cm and 50 cm in woa 3 and 50 cm and 80 cm in woa 4, which were the final positions. At 17 woa all birds were caught and individually marked with a spiral leg ring of a pen-specific color (Fieger AG, Tuttwil, Switzerland). In addition, 10 birds per pen (N = 5 LSL and N = 5 LB) were randomly selected as focal birds for health assessments and marked with an additional numbered leg ring for individual identification (N= 150 focal birds, N = 75 LSL and N = 75 LB).

Experimental Design

Both perches provided per pen were of the same perch type with 5 different perches being used in the study in total (n = 3 pens per perch type). Treatments were equally distributed within the barn ensuring comparable environmental conditions between treatment groups. All perches were commercially available with 2 of them quite new at the time of the study and only used on few farms while 3 of them already being commonly used for pullets and laying hens in Switzerland (Figure 1). Perches differed in shape and material as shown in Figure 1 with different combinations of the following shapes - square, mushroom, round - and materials - fiberglass, plastic and metal.

Data Collection

Behavior. Video recordings were conducted with 1 camera per pen (Samsung SNO-6083R, Samsung Techwin CO., Korea) using a customized video recording software (Multieye Hybrid Recorder Version 2.3.1.8, Artec technologies AG, Diepholz, Germany). During the rearing phase videos were recorded at 3, 6, 9, 12, and 15 woa whereas during the laying phase recordings took place at 18, 27 and 39 woa. Videos were analyzed by 1 trained observer who assessed the following quantitative (a) and qualitative (b) behaviors on 1 d per pen per woa:

a) Perch use: the number of birds sitting and standing on the perches was counted every 2 h beginning after lights on until lights off.

Walking on and transitions between perches: at 3 time points per day (i.e., after lights on, at midday and in the middle of the dusk phase) 5 min were analyzed continuously to count the number of walking bouts on and transitions between perches.

b) Each observed walking bout and transition was further assessed according to whether these behaviors occurred with or without problems (i.e., whether balancing problems while walking or unsuccessful landings during transitions occurred, ethogram see Table 1) and the percentages based on the total observations per variable were calculated.

Health Assessments of Focal Birds During Lay. Focal birds were assessed for different aspects of their health during the laying phase, which included:

a) Keel bone health: Keel bone health was assessed at 17, 20, 28, 32, 35 and 38 woa using a portable Xray unit (GIERTH HF 200 ML; X-ray tube Toshiba D-124 with maximal acceleration voltage of 100 kV; X-ray

Table 1. Ethogram of the various behaviors observed during the rearing and laying phase.

Behavior	Definition	
Sitting on perch	A hen is sitting on a perch	
Standing on perch	A hen is standing on a perch	
Walking on perch	A hen is walking on a perch (at least 3 consecutive steps). A walking bout started when the hen started walking and ended when the hen stopped walking.	a) Walking without problems: a hen is continuously walking on the perch without any signs of hesitation or instability. b) Walking with balance movements: a hen's body tilts on its axis while the tail feathers are spread and rapidly moving up- and downwards, once or repeatedly. The hen's neck may be simultaneously reached out. Wings are flapped, once or repeatedly.
Transitioning between perches	A hen is moving from 1 perch either to the other perch, to the ground or to the grid area assessed for both directions.	a) Successful transition: the hen is jumping on or off the perch with orientation behavior towards the landing site. The landing itself is safe with both feet touching the ground/grid area or perch and the body position is upright. b) Unsuccessful transition: a hen fails to land on the envisioned landing site (ground, grid area or perch) or leaves the perch unintentionally.

plate Canon CXDI-50 G; software Canon CXDI Control Software NE) at a distance of 80 cm and voltage of 46 kV/2.4 mAs. Hens were hung upside down with their feet in metal shackles fixed to a wooden frame to induce immobility as described by Sirovnik and Toscano (2017). Radiographs were imported to a Picture Archiving and Communication System (PACS; IMPAX EE, Agfa Healthcare, Bonn, Germany) as DICOM files. For scoring, radiographs were downloaded from the PACS as JPEG files. Xray images were analyzed by 1 trained examiner using a tagged visual analogue scale to assess keel bone fracture (**KBF**) severity according to Rufener et al. (2018). The severity scale goes from 0 to 10 with 10 being the most severe case of keel bone damage.

b) Footpad health: Assessment of footpad health included severity of pododermatitis, severity of toe injuries and severity of bumble feet and was conducted at 17, 32 and 38 woa using tagged visual analogue scales for each parameter (modified by Tauson et al., 1984 and Welfare Quality® Protocol, 2009). The severity scale goes from 0 to 10 with 10 being the most severe case of the assessed parameter. For the analysis, an overall score for both feet combined was calculated for each parameter per bird and woa.

c) Plumage condition: Plumage condition was assessed at 17, 32 and 38 woa using a tagged visual analogue scale for each of the 5 body parts including cloaca, breast, back, wing and tail (modified by Tauson et al., 1984 and Welfare Quality® Protocol, 2009). The severity scale goes from 0 to 10 with 10 being the most severe case of plumage condition. Plumage condition included a combination of degree of feather coverage as well as feather abrasion. Footpad health and plumage condition scores were assessed by 1 trained examiner and the scoring system used is further described in Gebhardt-Henrich et al., 2017. For the analysis, an overall score of all 5 body parts was calculated per bird and woa.

Statistical Analyses. Data were analysed using linear mixed-effects models (**LME**) and generalized linear-mixed effects models (**GLME**) in R (version 4.2.1) with RStudio as the user interface (version 4.2.1, RStudio Team, 2020) applying the package blme (Bates et al., 2015). Model assumptions were checked visually using q-q plots for LME and the package DHARMa for GLME (Hartig, 2022) to check for a normal error distribution and homoscedasticity of the residuals. We used dummy variables with sum contrasts for tested factors and interactions and standardized the independent continuous variable age when included in the models. *P*-values were obtained by comparing the full model including all main effects and interactions to models each reduced by 1 main effect or interaction only. The model comparison was performed using a parametric bootstrap approach with the function “PBmodcomp” from the “pbkrtest” package (Halekoh and Hojsgaard, 2014). Model estimates and 95 % confidence intervals (**CI**) were calculated for the full models and displayed using the package “effects” (Fox, 2003). Effects with *P*-values until $P < 0.1$ were considered for interpretation, which was based on model estimates and confidence intervals.

Effects on Behavior. To assess the effect of perch type on frequency of perch use, the response variable number of birds on perches (i.e., birds sitting and standing at a given timepoint) was square-root transformed and analyzed with perch type (categorical with 5 levels: square-fiber, mushroom-metal, mushroom-plastic, round-plastic, round-metal), age (continuous with 8 levels: 3, 6, 9, 12, 15, 18, 27, and 39 woa) and hybrid (categorical with 2 levels: LSL, LB) as well as the interactions perch type: age and perch type: hybrid as fixed effects. To account for repeated measures, pen was included as a random effect and sampling date as a crossed random effect.

Number of walking bouts was analysed as frequencies and proportions were calculated to obtain percentage of balance movements while walking. As observations revealed that transitions rarely included unsuccessful landings (i.e., out of 2,913 observed transitions, only 16 were not successful [0.55%]), the number of successful transitions was analysed as frequencies only. Models for each variable, i.e., number of walking bouts, % of balance movements and number of transitions, were analysed including perch type (categorical with 5 levels: square-fiber, mushroom-metal, mushroom-plastic, round-plastic, round-metal), age (continuous with 8 levels: 3, 6, 9, 12, 15, 18, 27, and 39 woa) and time of day (categorical with 3 levels: lights on, midday and dusk phase) as well as the interactions perch type: age and perch type: time of day as fixed effects. To account for repeated measures, pen was included as a random effect and sampling date as a crossed random effect.

Effects on Health During the Laying Phase. To assess effects of perch type on health of focal birds during the laying phase, response variables were KBF severity (continuous from 0.0 to 10.0), severity of pododermatitis (continuous from 0.0 to 10.0), severity of toe injuries (continuous from 0.0 to 10.0) and severity of plumage damage (continuous from 0.0 to 10.0). Toe injuries only occurred at a very low level (0.9 % of all birds) thus severity of toe injuries was not analyzed. The response variable severity of pododermatitis and KBF severity were log-transformed, and severity of bumble feet was analyzed as a binary variable (i.e., severity of bumble feet > 0) since it occurred in few birds only. For the variable KBF severity, woa 17 and 20 were excluded from the data set since no fractures were detected at these time points. Fixed effects included in the full models were perch type (categorical with 5 levels: square-fiber, mushroom-metal, mushroom-plastic, round-plastic, round-metal), age (categorical with 3 levels: 17, 32, 38 woa and for KBF severity with 4 levels: 28, 32, 35 and 38 woa) and hybrid (categorical with 2 levels: LSL, LB) as well as the interactions perch type: age and perch type: hybrid. To account for repeated measures, the random effect bird ID nested in woa nested in pen was included in the models.

RESULTS AND DISCUSSION

Use of Perches

The number of birds using perches increased with age ($P = 0.001$) and was influenced by hybrid with more white hybrids using the perches compared to brown hybrids (model estimates and 95% confidence intervals [CI] for LB: 4.78 [3.9, 5.7] and LSL: 11.05 [9.7, 12.5], $P = 0.001$). Chicks started using the perches as soon as they got access to them at 2 wk of age. This was expected, as other studies showed that chicks make use of perches if available already at 1 wk of age (Skånberg et al., 2021). Overall, the pattern of how perch use was developing with age was comparable to other studies looking at perch use in pullets (e.g., Heikkilä et al., 2006). Twice as many hens from the white hybrid used the perches compared to the brown hybrid (mean ± SD white hybrid: 13.9 ± 11.1 birds vs. brown hybrid: 6.8 ± 6.7 birds). These numbers match other studies showing differences in terms of perching behavior between different strains (e.g., Faure and Jones, 1982) and may be due to the white hybrids being lighter and performing more transitions and jumps compared to brown hybrids (Pufall et al., 2021).

There was a trend for perch type to affect perch use with the round-metal perch being used by fewer birds compared to the other perches (model estimates and 95% confidence intervals [CI] for round-metal: 2.18 [1.8, 2.6], square-fiber: 3.11 [2.7, 3.5], mushroom-metal: 3.06 [2.6, 3.5], mushroom-plastic 2.78 [2.3, 3.2] and round-plastic: 2.67 [2.2, 3.1], P= 0.09, Figure 2). The round-metal perch was only used half as much as the mushroom-metal perch, which was used the most (Figure 2). This is the first time that differences in perch use frequency was observed when birds were not provided a choice. Recent studies using preference tests regarding perch material, shape or diameter reported that the round metal perch often, but not always, performed worse when presented together with other perch types (Gebhardt and Fröhlich, 2010 but also see Chen et al., 2014). When comparing frequency of perch use between different perches, Pickel et al. (2010) did not find an effect of perch type and the authors argued that this was due to the overall high motivation of laying hens to use elevated structures irrespective of the comfort or suitability a perch provides. In the present study however, hens tended to use perches differently and used the round-metal perch less compared to other perch types, despite their strong behavioral need to perch (in adult hens: Olsen et al., 2000, 2002). Due to the low sample size of the current study, research is needed to investigate this trend further and confirm

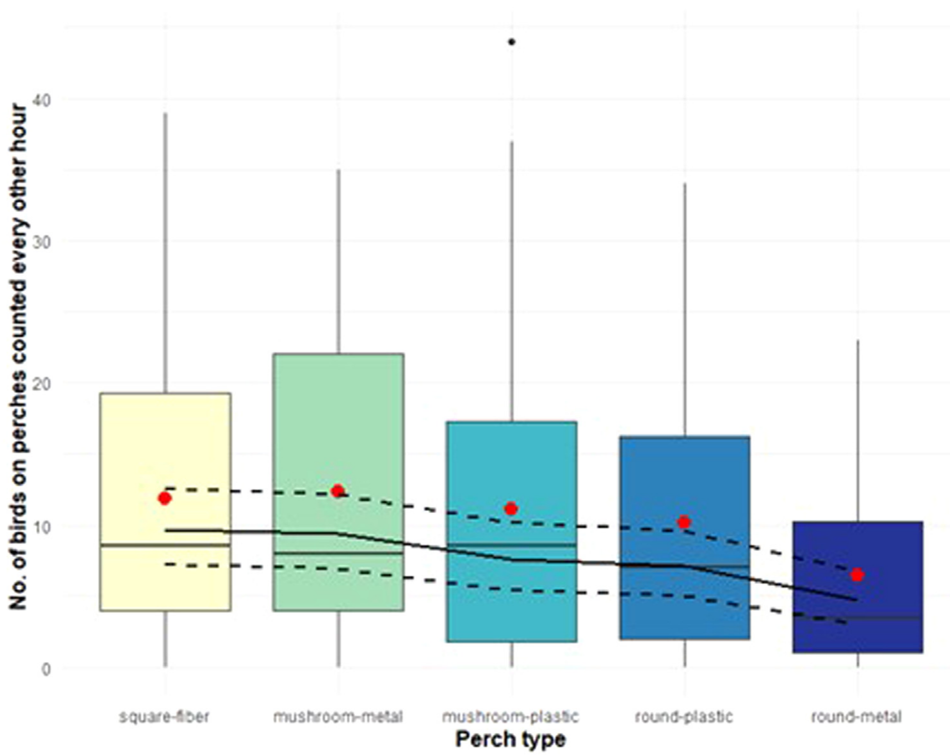

Figure 2. Frequency of perch use depending on perch type (P = 0.09). Boxplots represent the raw data and straight lines the model estimates with the dashed lines their 95% confidence intervals. The red dots represent the means for frequency of perch use per perch type.

tendencies observed in the current work as perch material is identified as an important factor by many other studies (see review by Bist et al., 2023). Factors that may explain why the round-metal perch was used the least may include slipperiness (Scott and MacAngus, 2004), thermoregulation as well as resting comfort (Pickel et al., 2011), factors that have been shown to influence perch related hen behaviors such as moving and resting on perches.

Behavior on Perches

The number of walking bouts performed on perches increased with increasing age ($P < 0.001$) and was affected by an interaction of perch type and TOD ($P = 0.028$, Figure 3). Similarly, the percentage of balance movements while walking on perches occurred more often with increasing age ($P < 0.001$) and was affected by the interaction of perch type and TOD (Figure 4, $P = 0.050$). The number of walking bouts on perches varied depending on time of day with most of the walking bouts observed during lights on specifically with the square-fiber, the mushroom-metal and the round-plastic perches (mean ± SD of number of walking bouts after lights on for square-fiber: 5.0 ± 4.8, mushroom-metal: 6.1 ± 7.5, round-plastic: 4.4 ± 4.4 vs. mushroom-plastic: 3.4 ± 4.3 and round-metal perch: 2.6 ± 3.3). Contrary to walking bouts, the percentage of balance movements was highest during the dusk phase as in 51.4 % of all observations balance movements were observed with different incidences between perch types (Figure 4). A general time of day effect for qualitative perch use is probably associated with the daily activity of laying hens, which is related to perch use (Campbell et al., 2016). For example, as the dusk phase is the time of the day where birds use the perches in preparation for night-time roosting, more space on the perches is occupied thus moving on perches is probably more difficult as less space is available. This would explain the overall higher percentage of balance movements at that timepoint. The highest percentage of balance movements during the dusk phase was observed in pens with the mushroom-metal and the mushroom-plastic perches. When taking both observations together (i.e., number of walking bouts and walking with balance movements), the 2 perch types differed in how often they were used for walking and how often walking was associated with balance movements. For example, after lights on birds with the mushroom-metal perch walked twice as much on perches compared to birds with the mushroom-plastic perch (average number of walking bouts on mushroom-metal perch: 6.1 vs. 3.3 for mushroom-plastic perch) but had the same amount of balance problems (on average both perch types showed balance movements in 2.2 % of walking bouts) assuming that the mushroom-plastic perch seems more difficult to handle for the birds. Variations in perch materials and sizes may explain these differences as studies on perch characteristics showed that relationships between a single perch characteristic such as material or shape and the variable of interest is often complex and inter-related with another characteristic. For example, even though the mushroom-plastic perch was wider in diameter than the mushroom-metal or the round-metal perch (width: 52 vs. 46 vs. 33 cm, respectively) and thus potentially associated with fewer balance movements as found in Pickel et al. (2010), we found more balance movements with this perch type. This was likely due to the material as plastic in general is assumed to be more slippery (Scott and MacAngus, 2004; slipperiness defined as a bird's foot being displaced on the perch in any direction and the bird having to react and correct its stance).

The number of transitions was affected by age ($P < 0.001$) and time of day ($P < 0.001$) as transitions increased with age and more transitions occurred during the dusk phase compared to midday and lights on. Perch type did not affect the number of transitions ($P = 0.345$). Unsuccessful transitions (i.e., unsafe landings or unintended transitions) between perches and between perches and the grid/ litter area were rarely observed. Out of 2,913 observed transitions, only 16 were not successful (0.55%) with 4 events occurring with the square-fiber perch, 2 events with the round-plastic perch, 1 event with the round-metal perch, 7 events with the mushroom-plastic perch and 2 events with the mushroom-metal perch. In comparison to the simple experimental set-up of the current study,

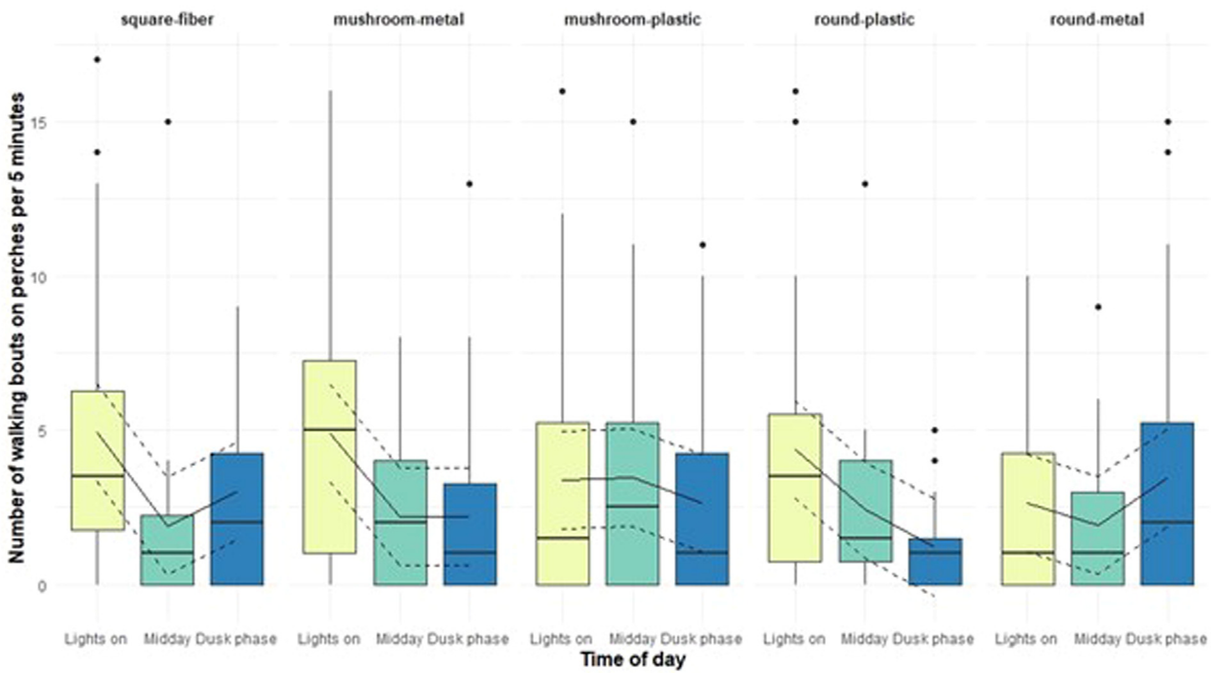

Figure 3. Number of walking bouts on perches during 5 min observation time presented for time of day and perch type (P = 0.028). Boxplots represent the raw data and straight lines the model estimates with the dashed lines their 95% confidence intervals.

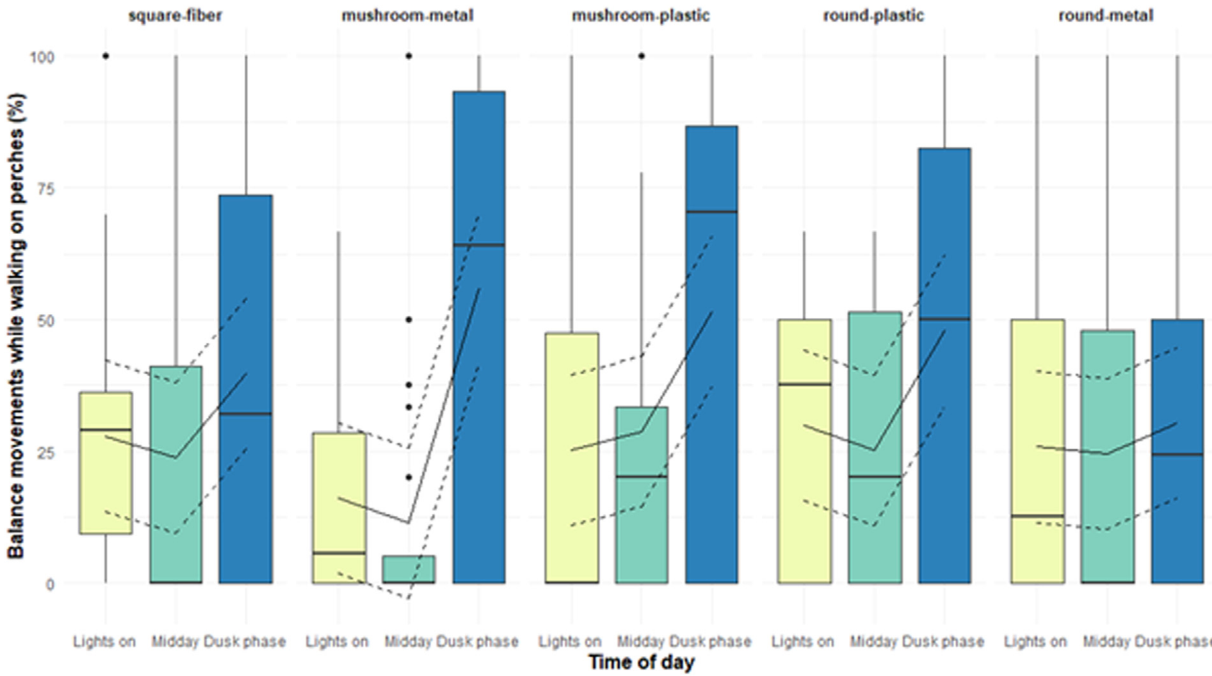

Figure 4. Balance movements while walking on perches (%) presented for time of day and perch type ($P = 0.05$). Boxplots represent the raw data and straight lines the model estimates with the dashed lines their 95% confidence intervals.

falls and collisions occur frequently in commercial settings with aviary systems specifically at dusk (Stratmann et al., 2019, Stratmann et al., 2015b). The fact that only few falls were observed in the current study thus probably has to do with the simple design of the pen set-up (i.e., low height and distance between the perches as well as simple arrangement) and the low population density. Overall, a conclusive statement on perch type comparison and suitability for laying hens in regard to qualitative behaviors seems difficult based on the outcome of the current study as next to perch type other potential associations with factors such as time of day have to be considered and replicated in future studies. In addition, the high observed variation within behavioral outcome measures complicates conclusive interpretation of the results, which is probably due to the relatively low sample size (n = 3 replicates per perch) used in the current study.

Health During the Laying Phase

Keel Bone Health. The severity of keel bone fractures was affected by age ($P < 0.001$) and hybrid ($P = 0.028$) with increasing severity with age (model estimates and 95% confidence intervals [CI] for woa 28: 0.82 [0.1, 0.9], woa 32: 1.20 [1.0, 1.4], woa 35: 1.35 [1.2, 1,6] and woa 38: 1.43 [1.2, 1.6]) and more severe fractures in the white hybrid compared to the brown hybrid (model estimates and 95% confidence intervals [CI] for LSL: 1.35 [1.1, 1.6] vs. LB: 1.02 [0.8, 1.2]. Perch type did not affect fracture severity ($P = 0.472$). Even though fracture severity was affected by age, it was assessed as very minor compared to data collected in commercial housing settings at that age. For example, Rufener et al., (2019) found an average severity degree of 5 at an age of 39 wk compared to 1.43 in the current study (with a score of 10 being the most possible severe score). In general, perches are associated with the occurrence of keel bone damage such as fractures and deviations, as they presumably play a role in connection with falls, e.g., when animals collide with the perches during a fall (Stratmann et al., 2015b) or deviations due to sitting on perches (Pickel et al., 2011, Stratmann et al., 2015a). In the present study however, birds only had minor fractures, which probably had to do with the simple perch arrangement and pen design. Compared to more complex commercial housing systems such as aviaries, there were only 2 levels of perches, the distances between perches and perches and the grid were short and the angles the birds had to jump were not steep. In addition, perch type did not affect fracture severity supporting the general conclusion that KBD is a multifactorial problem and not related to just 1 factor (Harlander-Matauschek et al., 2015). Lastly, in the current study only keel bone fractures were assessed not deviations, which is something to consider for future studies.

Footpad Health. Severity of pododermatitis was affected by hybrid ($P = 0.015$) and the interaction between age and perch type ($P < 0.001$). White hybrids had a higher severity degree of pododermatitis compared to brown birds (model estimates and 95% confidence intervals [CI] for LSL: 0.88 [0.8, 1] vs. LB: 0.74 [0.7, 0.8]. In terms of perch type, both mushroom shaped perches had higher scores for pododermatitis compared to the other perches in woa 32 when compared to woa 17 and 38. At 38 woa severity scores went down again in all perch types (Figure 5). However, the severity of pododermatitis was classified as minor with an average score across all perch types, ages and hybrids of 0.7. Such a score only involves a minor change to the footpad (i.e., areas affected by pododermatitis $\leq$ 0.5 cm) with the maximum possible score being 10. It is however interesting, that birds kept with both mushroom-shaped perches had a higher pododermatitis score at 32 and 38 wk of age compared to birds kept with the other perch types. As birds kept with the square-fiber perch had similar pododermatitis scores than birds with the mushroom-shaped perches, shape might not be the only factor explaining the results. In fact, the mushroom-metal and the square-fiber perches also had ridged surfaces to provide grip; something which may have allowed feces to remain on these perches for a longer duration, increasing the likelihood of the animals' feet of coming into contact with feces. The round-metal perch had the lowest severity scores for pododermatitis, which could be related to the smooth surface but also the

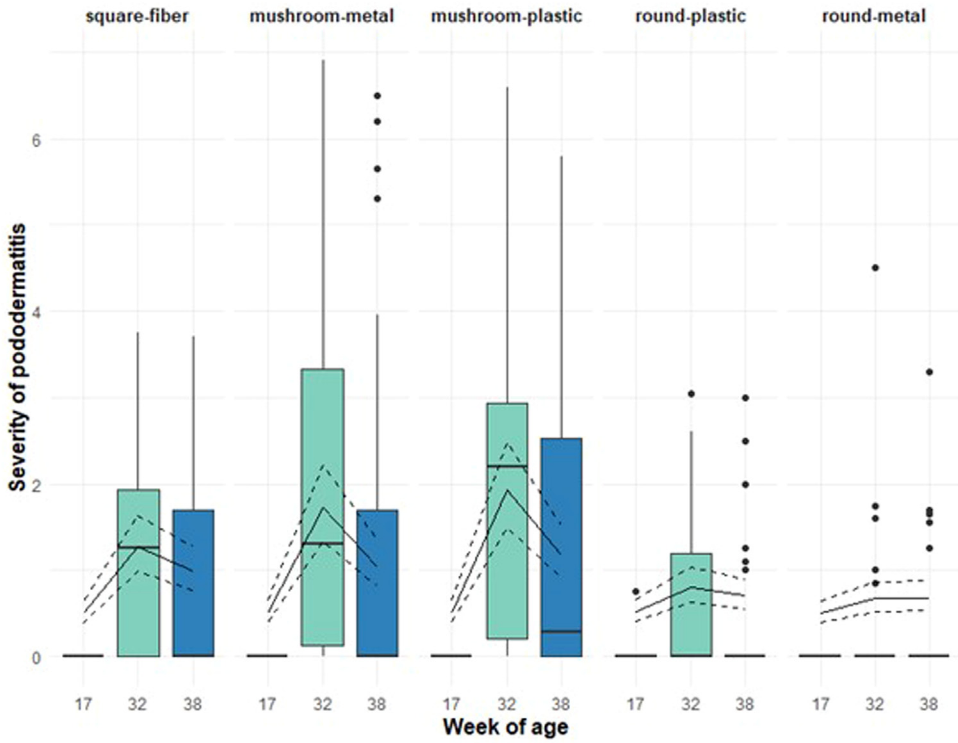

Figure 5. Severity of pododermatitis presented for wk of age and perch type ($P < 0.001$). The severity scale goes from 0 to 10 with 10 being the most severe case of pododermatitis. Boxplots represent the raw data and straight lines the model estimates with the dashed lines their 95% confidence intervals.

reduced use of the perch compared to the other perches.

Severity of bumble feet was affected by age ($P < 0.001$) with a higher score in woa 32 and 36 compared to woa 17. Hybrid and perch type did not affect bumble feet severity and overall, only 4% of all birds were affected by this condition. Toe injuries only occurred at a very low level which was 0.9% of all birds. These 2 health conditions were perhaps almost not present in this study as the experimental environment was much more controlled and the animal density was much lower than in commercial systems.

Plumage Condition. Plumage condition (degree of plumage coverage and plumage abrasion) was affected by hybrid ($P = 0.001$) and the interaction between age and perch type ($P = 0.007$). Plumage damage was more pronounced in the white compared to the brown hybrid (model estimates and 95% confidence intervals [CI] for LB: 0.19 [0.13, 0.25] vs. LSL: 0.5 [0.41, 0.53]). It was also higher in birds kept with the mushroom-metal perch at 38 woa when compared to the other perches and ages (Fig. 6). At 38 woa birds kept with the round-metal perch had the least plumage damage. Similar to food health, plumage condition was assessed as minor throughout the study (average score at 38 woa was 0.34 with the maximum possible score being 10). However, differences in plumage quality varied depending on the body part on which it was assessed. When looking at different body parts separately it became evident that the breast area of the birds was mostly affected (average severity score breast plumage: 1.5 vs. back: 0.01, tail: 0.2, cloaca: 0.0, wing: 0.05). This is the part of the body that is directly in contact with the perch while roosting. The mushroom-metal perch caused the most abrasion on the breast feathers, presumably due to its rough surface structure, explaining why birds in pens with this perch type had the poorest scoring for breast feathers compared to the other perch types with a clear difference at 38 woa. The

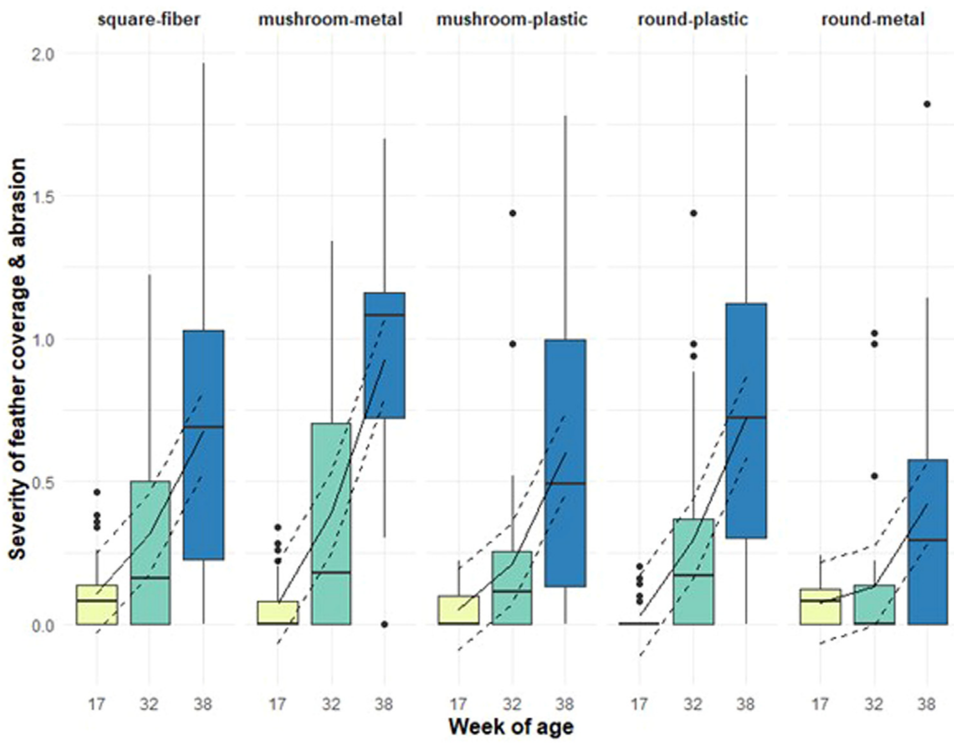

Figure 6. Plumage condition (degree of plumage coverage and plumage abrasion) presented for wk of age and perch type (P = 0.007). The severity scale goes from 0 to 10 with 10 being the most severe plumage condition including severe feather loss and/or damaged feathers. Boxplots represent the raw data and straight lines the model estimates with the dashed lines their 95% confidence intervals.

round-metal perch had the lowest severity scores for plumage condition, but similar to pododermatitis, this could be explained by the reduced perch use frequency of that perch type and its smooth surface. According to the author's knowledge, this is the first time that plumage condition was assessed with regards to perch type.

CONCLUSIONS AND APPLICATIONS

1. Perch types varying in shape, material and diameter affect behavior and health parameters in laying hens during the rearing and laying phase. However, when comparing the different perch types, advantages and disadvantages of each type for the welfare of the hens came into view with potentially complex inter-relationships between perch characteristics.
2. The round-metal perch seemed to do worse in terms of perch use and the mushroom-plastic perch in terms of moving behaviors on perches. On the other hand, both mushroom-shaped perches were used the most but were associated with more feet, plumage and balance problems. Further research is needed to confirm tendencies for perch material and shape on various outcome measures as found in this study.
3. As tested in the setting of the Swiss authorization procedure for farm animal housing systems, alternative perch types did not fare worse than the round-metal perch and even seemed to have advantages in terms of the birds' use and behavior.
4. As in commercial housing systems round-metal perches are the commonly used perches, future studies could investigate the effect of alternative perch types in commercial systems and consider new perch designs to ultimately improve welfare of laying hens.

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DISCLOSURES

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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