

# Perch use by broiler breeders and its implication on health and production

S. G. Gebhardt-Henrich,<sup>\*,1</sup> M. J. Toscano,<sup>\*</sup> and H. Würbel<sup>†</sup>

<sup>\*</sup>Center for Proper Housing: Poultry and Rabbits, Division of Animal Welfare, University of Bern, Switzerland; and <sup>†</sup>Division of Animal Welfare, VPH Institute, University of Bern, Switzerland

**ABSTRACT** Broiler breeders are commonly kept without perches, although perching has been shown to be a high-priority behavior in laying hens. We studied whether broiler breeders used elevated perches of different lengths during the night and how access to perches affected health and production. Using the Ross 308 hybrid, pens offering 4 different perch spaces per bird (5, 10, 14, and 20 cm) in a cross-over design were compared with pens without perches. The number of birds on perches at midnight were recorded 7 times during production. Prevalence of keel bone fractures, breast blisters, pododermatitis, and plumage quality of hens was assessed at 45 wk, and production was monitored daily. To determine subsequent effects on offspring, chicks from hens with and without perches

were reared and their growth rate was assessed. Analysis found more broiler breeders perched at night when 14 cm perch length per bird was provided than with less available perch length ( $P = 0.0005$ ), but there was no difference between 14 and 20 cm per bird. Perch use declined with age from about 50 to 20% ( $P < 0.0001$ ). The number of eggs and hatchability were not affected by treatment. During a period of high temperatures, mortality was lower in pens with perches ( $P = 0.001$ ). Keel bone fractures were present in 1/4 of hens and were not affected by the presence of perches. The growth of chicks was not affected by the parent treatment. In conclusion, our results suggest that perches were chosen for roosting by broiler breeders depending on their age and did not impair production.

**Key words:** broiler breeder, perch, behavior, production, health

2017 Poultry Science 96:3539–3549  
<http://dx.doi.org/10.3382/ps/pex189>

## INTRODUCTION

Roosting on aerial perches is a priority behavior of the ancestral species of both egg-laying and meat strains of chickens, though it has been studied principally in laying hens (e.g., Olsson and Keeling, 2000; Schrader and Müller, 2009; Donaldson et al., 2012). It is mainly considered an anti-predatory behavior in wild fowl (Newberry et al., 2001; Schrader and Müller, 2009). Consistent with this hypothesis, height is more important to the hens than the shape of the perch-like object (Schrader and Müller, 2009). Laying hens are willing to work to gain access for perches at night (Olsson and Keeling, 2002). Given the motivations that hens associate with perches and roosting at elevated positions, the provision of perches is mandatory in the EU for laying hens (CEC, 1999). In the EU, the provision of perches is not regulated for parent stock, and data on housing conditions of breeders of laying strains and broiler breeders are scarce. Perches are required for breeders of layers and broiler breeders in some European countries though the application to poultry other

than laying hens (e.g., broiler breeders) is inconsistent [EFSA Panel on Animal Health and Welfare (AHAW), 2010]. In Switzerland, the provision of at least 14 cm aerial perch per bird is mandatory for pullets, layers, and breeding stock, including broiler breeders (TSchV 2008 Table 9–12, 2014). In broiler breeders, restricted feeding and necessary equipment to feed males and females separately might make the installation of perches or use of aviaries difficult, though this may be dependent on genetic line, specifics of housing, and other factors. For instance, fast growing Ross broiler breeders in a commercial aviary system had similar production results compared with conventional floor housing (Damme, 1996), though no comparisons exist to consider other factors.

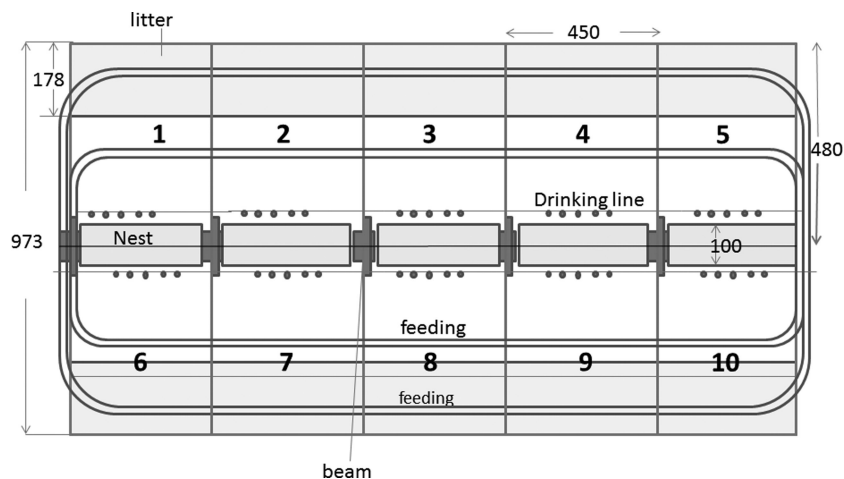
The provision of perches during rearing of broiler breeders is recommended ([http://en.aviagen.com/assets/Tech\\_Center/Ross\\_PS/Ross\\_PS\\_Handbook\\_2013\\_i-r1.pdf](http://en.aviagen.com/assets/Tech_Center/Ross_PS/Ross_PS_Handbook_2013_i-r1.pdf), accessed on 2–23-16) so that females are trained to move up to nest boxes later during production. Indeed, broiler breeders reared with perches lay fewer floor eggs than birds without perches (Brake, 1987). The broiler breeders with perches are also generally less fearful, as shown by shorter tonic immobility, than those without perches (Brake et al., 1994), which supports the anti-predator hypothesis for their function. Similarly, inclusion of perches

© 2017 Poultry Science Association Inc.

Received March 7, 2017.

Accepted June 13, 2017.

<sup>1</sup>Corresponding author: [sabine.gebhardt@vetsuisse.unibe.ch](mailto:sabine.gebhardt@vetsuisse.unibe.ch)



**Figure 1.** Top view of the pens in one barn. All measurements are in cm. The treatments that refer to the number of the pen are given in the text.

will train males to find the drinking water on the slats.

Perches also can lead to improved physical development. The presence of perches (provided they are used) will increase jumping and flying behavior of broiler breeders when perches are elevated and cannot be reached otherwise. This activity might influence body composition, metabolism, and possibly stress (if ability to perch is thwarted) of broiler breeders. Unfortunately, little is known about the response to perches in broiler breeders because they are commonly kept without perches [EFSA Panel on Animal Health and Welfare (AHAW), 2010]. Furthermore, the presence of perches likely influences mating behavior, because mating does not happen on perches and thus hens are able to avoid copulation.

In addition to effects on the hen, perches also may affect embryo and consequent chick development. Studies have found that stress that the hen experiences can affect oocyte development (e.g., broiler breeders: Babacanoglu et al., 2013; quail: Guibert et al., 2011; laying hens: Sas et al., 2006). Estrogens, corticosterone, and metabolic hormones are known to transfer between hen and oocyte, leading to differences in various post-natal expressions of different avian species, though mechanisms are not clear (see Groothuis and Schwabl, 2008 and references therein). Therefore, an influence of the presence of perches on egg parameters and chick growth is possible and requires study.

The objective of this study was therefore to assess the influence of perch space on the use of perches, as well as short-term (until peak of production) and long-term provision on production and health parameters, including the growth and health of their offspring. We hypothesized that housing broiler breeder hens without perches would subsequently suppress the growth rate in the broiler chicks (Ahmed et al., 2014).

## MATERIAL AND METHODS

### *Animals and Housing*

The experiment was approved by the cantonal Food Safety and Veterinary Office Fribourg (2013.26.FR+) and met all cantonal and federal regulations for the ethical treatment of laboratory animals.

Parent stock of the fast growing Ross 308 (<http://en.aviagen.com/ross-308/>, accessed on 2–25–2016) were obtained as one-day-old chicks at the end of October 2014 and maintained during production in 2 semi-detached barns. The barns had been converted from broiler barns into broiler breeder barns for this study. Automatic nest boxes (Volito BV, 3902HP Veenendaal, The Netherlands, 230 × 50 cm, 2 per pen) with a sloped bottom where eggs rolled onto a collecting belt covered by a wooden plate (25 cm) ran along the length of the middle of each of the 2 barns. Sloping down from the nestboxes were plastic slats (length: 248 cm) that were 88.5 cm above the floor at the wooden plate and 50 cm high adjacent to a 178 cm wide litter area (Figure 1). Two feeder lines were present: one on the litter and one on the slats. A drinking line with nipples was on the litter for approximately the first 6 weeks. Afterwards, this drinking line was removed, requiring the use of the drinking line in front of the nests. The bird density was 6.3 hens per m<sup>2</sup>, the feeding space per hen was 8.4 cm, and there were 7 birds per nipple on the drinking line. Litter consisted of wood shavings. Each barn was divided into 10 pens, 5 m wide. Six data loggers HOBO<sup>®</sup> U10–003 (Onset Computer Corp., Bourne, MA) recorded temperature and relative humidity above the litter and in the median height of aviary tiers and perches throughout the trials at 30 min intervals.

Female chicks were randomly assigned to pens. Males were housed in separate pens with perches between

**Table 1.** Design of the cross-over study. The numbers in the table show the length of perch [cm] available per bird during the indicated ages. The number of the pens refers to Figure 1. Example: Pens 1 and 8 had 5 cm perch space per bird up to 24 wk of age; from 25 to 28 wk, they had 10 cm; from 29 to 32 wk, 20 cm; and from 33 to 36 wk, 14 cm.

Pens	Age [WOA]			
	Up to 24	25 to 28	29 to 32	33 to 36
1, 8	5	10	20	14
5, 7	20	5	14	10
4, 6	10	14	5	20
2, 9	14	20	10	5

rearing and 19 wk of age (**WOA**) and then assigned to the pens with females following the recommendations of Aviagen<sup>TM</sup> (2012). From 19 WOA, each pen housed 119 females and 12 males. Control pens were equipped as described above and were in pens 3 and 10 in each barn (see Figure 1). Two horizontal wires were mounted above the drinker in the control pens to prevent animals from perching on the drinker tube. The other pens were equipped with wooden perches (6 × 5.5 cm, 50 cm above the slats) of different lengths from 3 to 20 WOA, after which perch space per bird was varied across 5, 10, 14 (legal minimum in Switzerland), and 20 cm in a cross-over design with the 4 treatments counterbalanced across 4 periods of 4 wk each from 20 to 36 WOA (Table 1). Video recordings (described in detail later) were made at the conclusion of the 4-week period in order to provide the birds with sufficient time to get accustomed to the new perch length. During rearing, when few birds perch (Gebhardt-Henrich et al., 2014), all birds except those in control pens were able to experience perches. Relatively broad rectangular perches were chosen because of the large size of broiler breeders and their preference for this shape (Muiruri et al., 1990) and a more favorable distribution of pressure from rectangular than round perches (Pickel et al., 2010). Perches were mounted over the feeder and drinker, and, if needed, parallel to the feeder and drinker. Each treatment, including the control without any perch, had 4 replicates (2 in each barn). At 36 WOA, all perches were removed in half of the pens to test the hypothesis that birds that had experienced the treatments with perches would show a carry-over effect compared with birds within control

pens. In order to rule out position effects in the barn, perches in pens 1, 5, 6, and 9 of barn 1 and in pens 2, 4, 7, and 8 of barn 2 were removed.

Brooding eggs from breeders at 33 WOA were hatched at one hatchery in the same setter and the same hatcher in different drawers on the same carriage. Two people from the hatchery, including one employee responsible for experiments, were present at hatching. The broiler chicks (offspring) from parent birds with and without perches were reared for 37 d in a broiler barn (Aviforum, Zollikofen, Switzerland) in 4 pens each. From parents without any perches and from parents with different perch lengths, 2,160 eggs were incubated and yielded 1,708 chicks at a fertility rate of 79.07% from parents without and 1,961 chicks at a fertility rate of 90.79% from parents with perches. Each pen (20 m<sup>2</sup>) contained 270 chicks of both sexes from either group of parents and provided 8% of the total area as sloped elevated platforms (2.4 × 0.65 m, between 17 and 25 cm high) and access to verandas (2.4 × 2.2 m). Verandas had a concrete floor with litter, a roof, and wire netting on the sides. Litter consisted of straw meal pellets, and standard starter and fattening diets were provided (UFA, Sursee, Switzerland).

**Management** After ad libitum feeding for 2 wk, broiler breeder chicks were fed restrictively following guidelines of their breed (Aviagen<sup>TM</sup>, 2012). Animals were weighed weekly (Mettler Toledo ICS425, Mettler-Toledo GmbH, CH-8606 Greifensee, Switzerland) in groups of 10 randomly selected birds per pen for the first 3 wk and afterwards 5 birds per pen individually until the end of production. Thus, at each time, 50 females and 10 males per barn were weighed in equal numbers from all pens. Based on the gain in body mass, the feed amount was adjusted to maintain body mass within the recommended allowance. Samples of feed from both barns were collected when the animals were 8, 16, 24, and 32 WOA and analyzed by LUFÄ, Oldenburg, Germany (Table 2). Water was provided ad libitum at all times. Following recommendations for the Ross 308 (Aviagen<sup>TM</sup>, 2012), the lighting schedule was: 22 h of daylight during the first d, then gradually reduced to 8 h until 3 WOA, and then increased to 14 h after 19 WOA. The light period was increased by one h from 53 WOA to boost production. At 17 WOA, males of the female line were culled. At 19 WOA, birds were mated. Birds were depopulated at 55 WOA. Eggs were

**Table 2.** Analyzed feed composition: Crude protein (N × 6.25) was determined by the method VO (EG) 152/2009, III, C, crude fat B (with HCL) by the method VO (EG) 152/2009, III, H, starch (EG) 152/2009, III, L, total sugar (EG) 152/2009, III, J, metabolizable energy for poultry (EG) 152/2009, VII, calcium and phosphorus by the method DIN EN 15,621.

Age [wk]	Protein [%]	Fat [%]	Starch [%]	Sugar [%]	Energy [MJ/kg]	Ca [%]	P [%]
<8	17.9	3.7	42.1	3.8	11.6	1.01	0.6
<16	14.5	4.6	42.1	3.2	11.3	1.17	0.62
<24	14.7	5.9	39.9	3.3	11.4	3.56	0.65
>24	13.6	5.2	46.7	2.3	12.0	3.01	0.54

brought weekly to a commercial hatchery where they were hatched.

## Data Collection

The number of eggs and whether they were laid in the nestbox, the litter, or on the slats were recorded daily, as well as the number of eggs that were cracked, small (< 50 g), or with double-yolk. Cracked and small/double-yolk eggs were not counted as brooding eggs. The numbers of eggs were summed over the production period for each pen to avoid age-related changes of laying rates. Fertilization and hatching rates were determined separately for birds with and without perches, regardless of treatment (i.e., perch length). Fertilization and hatching rates also were determined for each pen at 45 WOA. Mortality was assessed daily by pen and sex. At 46 WOA, 10 hens from each pen were caught in a stratified manner from all areas (litter, slats, perches) and scored for plumage, breast blisters, wounds, hock burn, pododermatitis, and keel bone damage. Scoring was conducted by one person who was blind to treatment. At the same time, birds were weighed to the nearest g, and the cleanliness of the back was subjectively rated on a 3-point scale. Birds with clean feathers (category 1) were distinguished from birds with feathers covered with traces of feces or litter (category 3) and birds with discolored feathers but not covered with particles like feces or litter were assigned to category 2. Keel bones were palpated following the method by Scholz et al. (2008). Hens were held with one hand and palpation was performed by running 2 fingers along the edge of the keel bone in order to detect deviations, bumps, or depressions. The scoring system consisted of 4 categories, including no damage (score 4), slight (3), moderate (2), and severe damage (1). Plumage was scored using the assessment protocol for laying hens based on the scale of Tauson (Welfare Quality<sup>®</sup>, 2009). For each body part, a sheet with a 10 cm long visual analogue scale was superimposed on a diagram of the 4 scores represented on a linear line (Tuytens et al., 2009). The pictures of white laying hens from Welfare Quality<sup>®</sup> (2009) were used as a reference for scoring. A mark was placed on the visual analogue scale, and then later the distance of the mark from the origin was measured with a ruler. Measurements of plumage were done in this manner for the neck, breast, cloaca, back, wings, and tail. Scores of the different body parts were added to yield a composite plumage score. A visual analogue scale also was used for wounds, marks on the comb using the Welfare Quality<sup>®</sup> protocol for laying hens, and for pododermatitis and hockburn using the protocol for broiler chickens (Welfare Quality<sup>®</sup>, 2009). Bumblefoot and breast blisters were noted if present. Evaluation of laying condition was performed at the time of scoring; all assessed hens were considered to be in laying condition because the width of their pelvic bones exceeded 3 fingers (about 3 cm) (Schridder, 2007). To estimate

observer reliability, the scoring of all variables of 10 hens was repeated at the end of scoring.

All animals, including those in control pens, were filmed for a 24-hour period at 24, 28, 32, 36, 43, 49, and 54 WOA, i.e., shortly before the length of the perches was changed (Samsung IP cameras and Multi-eye recording device, Artec Technologies AG, Diepholz, Germany). At 0:00 and 23:59 h, the number of birds on the slats, perches, and feeders was recorded for each pen.

During rearing of the offspring, broiler chicks stepping on a scale (Fancom Tierwaagen, NL-5981 Panningen, Netherlands) suspended from the ceiling of each pen were automatically weighed. Footpads and hocks of 10 randomly selected male and 10 female chicks per pen were scored on d 29 and 36 after hatching, using the Welfare Quality<sup>®</sup> protocol (Welfare Quality<sup>®</sup>, 2009).

## Statistics

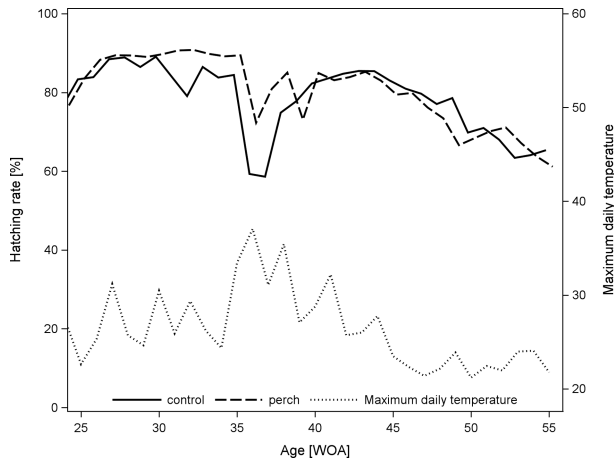
Continuous data were analyzed by mixed models using pen as the subject and post-hoc contrasts were computed (SAS<sup>®</sup>, Proc Mixed, Cary, NC, USA). Tukey's adjustment for post-hoc multiple comparisons was used.

All possible interactions were initially included in the models and successively removed if *P*-values exceeded 0.2. The fit of models was checked by examining residual plots.

Differences among treatments of body mass gains were analyzed using a mixed model (SAS<sup>®</sup>, Proc Mixed) with intercept and the linear effect of age as random effects. Pens nested in barns were used as independent subjects. For age, linear, quadratic, and cubic terms were used. First, hens in pens initially with and without perches independent of perch length were compared. In a second analysis, hens in pens with different perch lengths during rearing were compared. Due to the small number of males that were weighed, only data from females were analyzed. For the same reason, mortality was analyzed only in females with a binomial model with the logit link function (SAS<sup>®</sup>, Proc Glimmix). Relative risks with 95% confidence limits were calculated with Proc Freq, SAS<sup>®</sup>. Pododermatitis and hockburn in the broiler chicks (offspring) were analyzed as binomial variables (present or absent) (SAS<sup>®</sup>, Proc Genmod) using pen nested in treatment as the subject variable.

The repeatability of normally distributed data like plumage and health scores was calculated using the linear mixed-effects model "rpt.remlLMM," and for binary data (e.g., blister yes/no) "rpt.binomGLMM.multi" in R was used (Nakagawa and Schielzeth, 2010).

The 2 time points 0:00 and 23:59 h were taken as replicates and analyzed as repeated measures of each pen as the subject variable. The percentage of animals in the mentioned locations at night was analyzed as the outcome variable in a mixed linear model



**Figure 2.** Hatching rates of eggs from pens with and without perches and the daily maximum temperatures (lower dotted line) averaged for each wk during production.

(Proc Glimmix, SAS<sup>®</sup>). Age, perch length during rearing, and treatment were fixed factors, and pen was taken as a random factor. All measures on the same pen were not independent and were analyzed as repeated measurements by specifying pen as the subject variable, which was nested in the random factor barn to account for barn effects. Age was modeled as a continuous variable, and all other variables were categorical. Pens without perches were excluded from the analysis of percentage of birds perching. Since the statistical contrast between control pens and pens in which perches had been removed after 36 WOA was not different ( $P > 0.4$ ), these two categories were pooled. Post-hoc multiple comparisons were adjusted according to Scheffe's procedure (Proc Glimmix, SAS<sup>®</sup>). To check the influence of perch length during rearing, this variable was taken as a supplemental categorical factor for a subset of the dataset from 28 WOA onwards. At 24 WOA, the perch length during treatment was the same as the actual treatment so the influence of perch length could not be tested for the complete dataset.

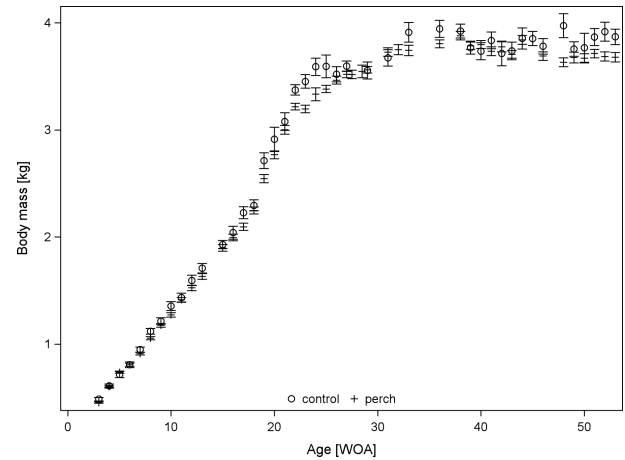
## RESULTS

### Environmental Data

On 4 d during production, temperatures exceeded 36°C (July 3 through 7 after 14:00, Aug. 7 after 15:00 local time). The relative humidity during those hot d was below 45%. Apart from this period and during 3 d at the end of December 2014 and January 2015 when the temperatures went below 10°C, the temperature values followed the management guide of Aviagen<sup>™</sup> (Aviagen<sup>™</sup>, 2012) (Figure 2).

### Body Mass

Body mass gains of females differed between pens with and without perches (interaction between age and treatment for the linear age term:  $F_{1,2852} = 3.84$ ,



**Figure 3.** Body mass of Ross 308 females without (circles) and with (plus) perches. The mean (respective symbol) and the SE (vertical bars) are shown.

$P = 0.05$ , quadratic age term:  $F_{1,3341} = 4.51$ ,  $P = 0.03$ , cubic age term:  $F_{1,3334} = 5.24$ ,  $P = 0.02$ ) (Figure 3). There was no effect of the removal of perches at 36 WOA ( $F_{1,1046} = 0.08$ ,  $P = 0.78$ ) or of perch length during the rearing phase on body mass gain ( $F_{3,19} = 1.48$ ,  $P = 0.25$ ). If only growth during rearing (before mating at 19 WOA) was considered, initial perch length affected growth as shown by a significant interaction with the cubic age term ( $F_{3,415} = 2.76$ ,  $P = 0.04$ ).

### Mortality

An average of one hen per 2 d died across the entire production cycle. During 3 unusually hot d (Figure 2), mortality was greatly increased, and 36 hens died between July 4 and 6, 2015. Mortality during these 3 d was lower in pens with perches ( $F_{1,16} = 15.38$ ,  $P = 0.0012$ ), and the relative risk to die in pens without perches was more than 3 times higher [rel. risk w/o perch: 3.66 (1.92–6.98), rel. risk with perch: 0.97 (0.96–0.99)] during these 3 days.

### Eggs

The number of brooding eggs per hen-housed was not related to treatment ( $F_{2,17} = 1.15$ ,  $P = 0.34$ ) nor was the number of floor eggs ( $F_{2,17} = 1.89$ ,  $P = 0.18$ ) or hatching rates at 45 WOA ( $F_{2,14} = 2.94$ ,  $P = 0.09$ ) (Table 3).

### Health

**Observer Reliability** The weighted kappa value was 1.0 for keel bones and the presence of blisters and 0.740 for dirt on the plumage. The repeatability of scoring the plumage condition was  $0.983 \pm 0.015$ . The repeatability of scoring of pododermatitis was  $0.816 \pm 0.139$ . Scoring wounds had a repeatability of  $0.985 \pm 0.017$ .

**Table 3.** Production data. Eggs/hen [HHA]<sup>1</sup> denotes eggs per initial hen without very small and double-yolk eggs. Percent of floor eggs include eggs laid on the litter, the slats, and aviary tiers. Weekly values of hatching rates were averaged but for pens with perches which were removed only data from wk 37 onwards were considered. Only clean, unwashed eggs were used for calculating the hatching rate. C—control pens, P—pens with perches, P rem—perches were removed after 36 WOA.

Treatment	Eggs/hen SE = 0.001			% Floor SE = 0.4			% Hatch SE = 1.6		
	C	P	P rem.	C	P	P rem.	C	P	P rem.
	116.6	113.4	107.4	11.0	6.9	8.5	77.7	80.1	81.7

<sup>1</sup>HHA—Hen-housed average.

**Table 4.** Overview on plumage and footpad of hens [%] at 46 WOA according to treatments. Analyses of plumage and foot conditions were performed on continuously scaled data from a visually tagged analogue scale, which was back-transformed to 4 categories (quartiles) comparable to the Welfare Quality Protocol for white laying hens (plumage) and for broilers (foot) (Welfare Quality®, 2009) in this table. Thus, the higher the quartile of the trait plumage the better the plumage, but the higher the quartile of the trait foot the more severe pododermatitis. Quartile 1 refers to healthy feet, quartile 2 to hyperkeratosis, and quartiles 3 and 4 to stages of pododermatitis. The 4 categories of keel bones (labeled keel) refer to the validated scoring system of Scholz et al. (2008). Categories 1 and 2 refer to fractures, category 3 to deviated keel bones, and category 4 to intact keel bones. Plumage scores for head, neck, back, breast, and tail were added up to one composite score. Control pens never contained perches; the treatment “perches” included pens that always contained perches and pens where perches had been removed after wk 36.

Quartile	Control				Perches			
	1	2	3	4	1	2	3	4
Plumage	0	25	65	10	4.4	30.6	57.5	7.5
Foot	40	25	25	10	40.6	39.4	18.8	1.3
Keel	0	20.5	10.3	69.2	0	25.8	14.5	59.8

**Keel Bones** A quarter of hens (24.75%) had moderately to severely deformed keel bones indicative of fractures, and 62% had intact keel bones. There was no difference in keel bone damage in pens with and without perches ( $F_{1,18} = 0.55$ ,  $P = 0.47$ ) (Table 4).

**Plumage** Plumage condition was associated with the presence of perches and body mass (perches:  $F_{2,17} = 6.13$ ,  $P = 0.01$ , body mass:  $F_{1,75} = 3.88$ ,  $P = 0.05$ , interaction:  $F_{2,175} = 5.78$ ,  $P = 0.004$ ). In pens without perches, hens heavier than 4 kg had intact plumage, especially on the back. The positive relationship between body mass and plumage condition was not present in pens with perches. The cleanliness of plumage did not differ among treatments (Table 4).

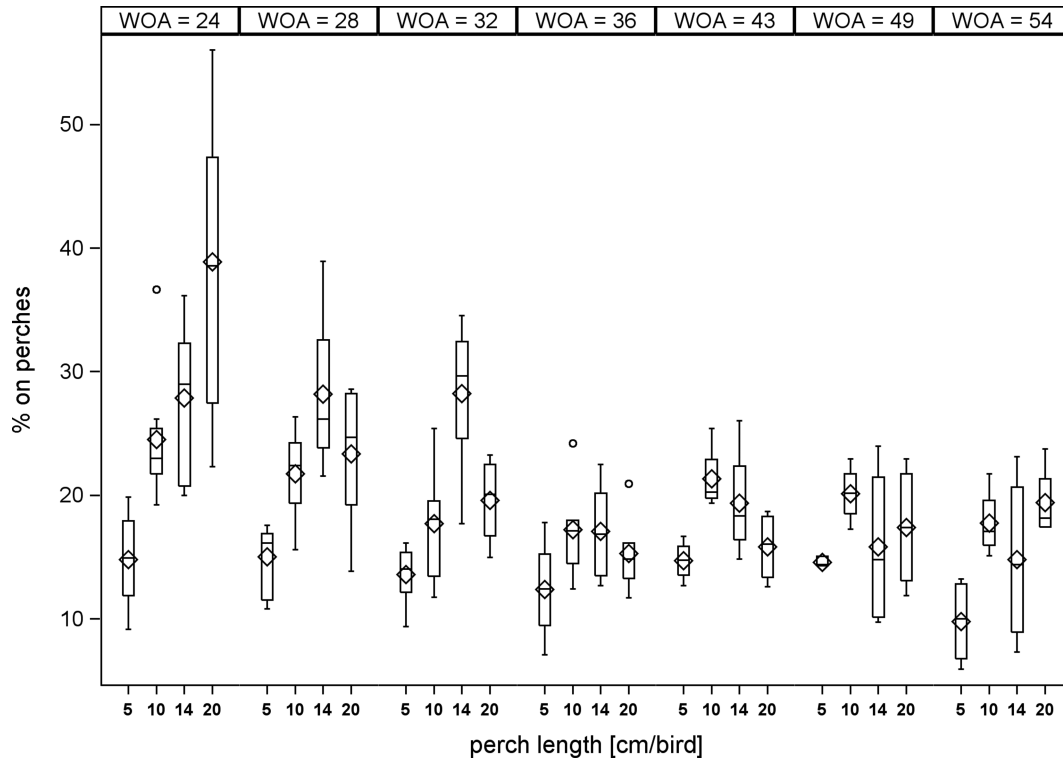
**Pododermatitis** Similarly to plumage, pododermatitis was influenced by the presence of perches and associated with body mass (perches:  $F_{1,18} = 4.54$ ,  $P = 0.047$ , body mass:  $F_{1,177} = 10.15$ ,  $P = 0.002$ , interaction:  $F_{1,177} = 4.83$ ,  $P = 0.03$ ). Hens from pens without perches had more pododermatitis (cf. scores 2 to 4 in Welfare Quality®, 2009) and fewer cases of hyperkeratosis (cf. score 1 in Welfare Quality®, 2009) than hens from pens with perches (Table 4). The heavier the hen was, the more severe the score of pododermatitis.

Bumblefoot did not occur. The prevalence of blisters and wounds was rare and unrelated to treatments.

**Offspring** Growth of offspring was not related to the treatment of the parents in the analysis of the factor treatment and interactions between treatment and age ( $P > 0.4$ ). Neither pododermatitis nor hockburn were influenced by the housing system of their parents, but males were more likely to have hockburn than females (footpad: no signs of pododermatitis 105 cases, some signs of pododermatitis 53 cases, treatment:  $\chi_1^2 = 1.27$ ,  $P = 0.26$ ; sex:  $\chi_1^2 = 1.09$ ,  $P = 0.30$ ; interaction:  $\chi_1^2 = 2.31$ ,  $P = 0.13$ ; hockburn males: 41 of 79 cases were without signs of hockburn, females: 55 of 79 cases were without signs of hockburn, treatment:  $\chi_1^2 = 2.54$ ,  $P = 0.11$ ; sex:  $\chi_1^2 = 5.48$ ,  $P = 0.02$ ).

## Perching Behavior

Perching at night was influenced by treatment (perch length per bird), perch length during rearing, and age, whereby the number of perching birds declined with age until perch use was similar across treatments (full dataset: treatment:  $F_{3,141} = 15.81$ ,  $P < 0.0001$ , age:  $F_{1,141} = 25.58$ ,  $P < 0.0001$ , interaction:  $F_{3,141} = 5.31$ ,  $P < 0.002$ ; dataset after 28 WOA: treatment:  $F_{3,109} = 42.11$ ,  $P < 0.0001$ , age:  $F_{1,109} = 9.41$ ,  $P < 0.003$ , perch length during rearing:  $F_{3,109} = 10.8$ ,  $P < 0.0001$ , age x perch length during rearing:  $F_{3,109} = 12.3$ ,  $P < 0.0001$ ) (Figure 4, Table 5). There were more perching birds with 10 cm perch length per bird compared with 5 cm (estimate  $-0.23 \pm 0.097$ ,  $t_{141} = -2.34$ ,  $P = 0.02$ ) and more birds with 14 cm than with 10 cm (estimate  $-0.35 \pm 0.099$ ,  $t_{141} = -2.34$ ,  $P = 0.02$ ). No difference was found between 20 cm and 14 cm perch length per bird (estimate  $-0.006 \pm 0.097$ ,  $t_{141} = -0.06$ ,  $P = 0.95$ ). The opposite pattern was found for the number of birds on the slats (treatment:  $F_{4,237} = 33.54$ ,  $P < 0.0001$ , age:  $F_{1,237} = 21.19$ ,  $P < 0.0001$ , interaction:  $F_{4,237} = 12.83$ ,  $P < 0.0001$ ) (Figure 5). There were fewer birds on the slats in pens with initially 5 cm compared with control pens (estimate  $-0.23 \pm 0.076$ ,  $t_{237} = -3.05$ ,  $P = 0.003$ ) and more birds with 10 cm compared with 14 cm perch length but not between 5 cm and 10 cm and between 14 cm and 20 cm (10 vs. 14: estimate  $0.43 \pm 0.085$ ,  $t_{237} = 5.04$ ,  $P < 0.0001$ , other comparisons:  $P > 0.47$ ). Perch length during rearing and its interaction with age influenced the number of birds on the slats after 28 WOA



**Figure 4.** Number of birds that were on the perches at night, depending on perch length per bird [cm]. The horizontal line depicts the median, the diamond shows the mean, and the box includes data ranging from the 25th to the 75th percentile. WOA—weeks of age.

**Table 5.** Least squares of percentages of broiler breeders on the perches, slats, or feeders at midnight. SE—Standard error. Different superscripts indicate different means with  $P < 0.05$ .

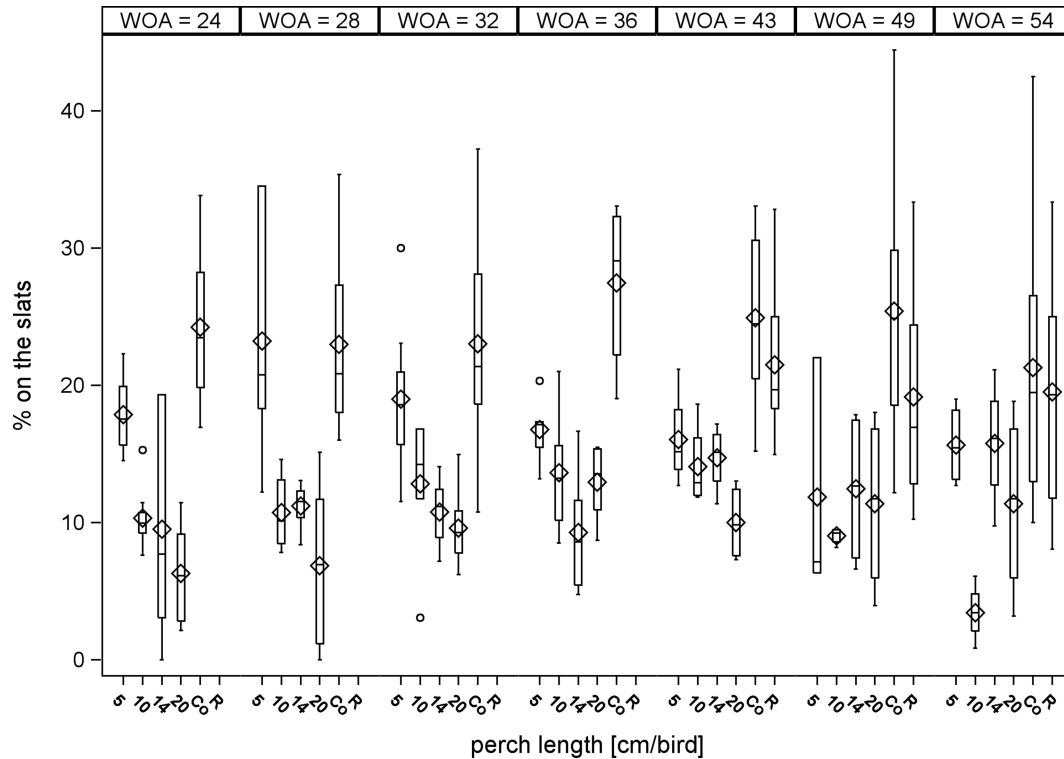
	control	5	10	14	20	SE
perch	N/A	0.34 <sup>a</sup>	0.60 <sup>b</sup>	0.62 <sup>c</sup>	0.68 <sup>c</sup>	0.05
slats	0.66 <sup>a</sup>	0.45 <sup>b</sup>	0.30 <sup>b</sup>	0.35 <sup>c</sup>	0.31 <sup>b</sup>	0.02
feeders	0.34 <sup>a</sup>	0.21 <sup>b</sup>	0.09 <sup>b</sup>	0.07 <sup>b</sup>	0.04 <sup>b</sup>	0.02

(treatment:  $F_{4,197} = 44.37$ ,  $P < 0.0001$ , age:  $F_{1,197} = 5.43$ ,  $P = 0.02$ , perch length during rearing:  $F_{4,197} = 3.65$ ,  $P < 0.007$ , interaction:  $F_{4,197} = 4.5$ ,  $P < 0.002$ ). A similar pattern can be seen with the number of birds perching on the feeders with decreasing numbers the more perch length was available (treatment:  $F_{4,241} = 139.91$ ,  $P < 0.0001$ , age:  $F_{1,241} = 3.93$ ,  $P = 0.049$ ) (Table 5), but perch length during rearing was not significant (treatment:  $F_{4,201} = 113.22$ ,  $P < 0.0001$ , age:  $F_{1,201} = 0.76$ ,  $P = 0.38$ , perch length during rearing:  $F_{4,201} = 0.19$ ,  $P = 0.94$ ). Numbers of birds on the feeders were different between control pens and pens with 5 cm perch length per bird and between 5 and 10 cm (estimate  $0.12 \pm 0.015$ ,  $t_{2417} = 8.43$ ,  $P < 0.0001$  and estimate  $0.12 \pm 0.013$ ,  $t_{241} = 9.06$ ,  $P < 0.0001$ ).

## DISCUSSION

Perch use at night depended on the length of perch available per bird, perch length during rearing, as well as on age. With decreasing perch length per bird, more birds were found sitting on the slats and the feeders

at night, which suggests those structures seem to serve as an alternative, albeit less preferred, perching structure. Positive effects due to enriched housing like the provision of perches must be counterbalanced with economical losses and health problems (Brake, 1998). In the present study, the number of brooding eggs and chicks per hen-housed was not affected by the provision of perches. However, the number of brooding eggs and the percentage of floor eggs may have been influenced by the observed consumption of eggs on the floor and in the nests by males (unpublished observations). Although perches did not seem to associate with health parameters, such as keel bone damage or pododermatitis, the study does suggest that perches could have positive effects on survival and hatching rates during heat stress. Heat stress was not applied in a controlled manner so the direct causes of elevated temperatures on mortality and hatching rates are unclear. The behavior of broiler breeders is affected by thermal conditions and at  $35^{\circ}\text{C}$  more prostration occurs than at  $21^{\circ}\text{C}$  (Pereira et al., 2007). From  $33^{\circ}\text{C}$ , broiler breeders are measurably stressed, and plasma glucose and cholesterol increase (Xie et al., 2015). Above external temperatures of  $32^{\circ}\text{C}$ , the body temperature of broiler breeders increases by  $1^{\circ}\text{C}$  per h (McDaniel et al., 1995). Sperm quality and subsequent fertility correlates negatively with male body temperature (McDaniel et al., 1995; Karaca et al., 2002), which would explain lower hatching rates of the current study following the episode of temperatures above  $35^{\circ}\text{C}$ . Heat stress also negatively affects egg production, egg quality (Mack



**Figure 5.** Number of birds that were on the slats at night, depending on perch length per bird [cm]. “C” denotes control pens that never had perches, and “R” denotes pens where perches had been removed after 36 WOA. The horizontal line depicts the median, the diamond shows the mean, and the box includes data ranging from the 25th to the 75th percentile. WOA—weeks of age.

et al., 2013 and references therein.), and the immune system, and increases mortality in laying hens (Mashaly et al., 2004). It is possible that birds on perches could dissipate heat better than birds in the same position on the litter or slats (LeVan et al., 2000), which may explain the reduced mortality and a less pronounced drop in hatching rates in pens with perches during the abnormally high temperatures.

The identified interactions between the presence of perches and body mass for the responses of plumage quality and pododermatitis suggest the existence of mechanisms that should be investigated. For instance, from observations during farm visits, there was no evidence for severe feather pecking, which also could have caused damaged feathers. Alternatively, damage of plumage in hens might have been caused by the treading of the males during copulation (Moyle et al., 2010 and references therein). Broiler breeder males often force matings (Jones and Prescott, 2000). Large hens might be more difficult for males to force to mate, and reduced frequencies of copulation could lead to more undamaged feathers on the back.

Although an interaction between the presence of perches and body mass on pododermatitis was found, the relationship may not be causal. A high body mass might favor pododermatitis, as more pressure is put on the footpad, but body mass per se has not been found to correlate with foot condition in laying hens (Tauson and Abrahamsson, 1996) or broiler breeders in cages (Pearson, 1983). The presence of perches improved foot

health in broiler breeder hens, but since those birds were kept in cages with wire floors, a comparison with the present study is not possible. Perches are also known to improve foot health in broilers, and Kiyama et al. (2016) speculated that this might be linked to higher litter quality in the presence of perches, although litter quality was not assessed in their study. In a study by Kaukonen et al. (2016), poorer litter quality and wetness were associated with poorer footpad health but not with the prevalence of severe lesions. In the present study, perches that were above the manure pit might have reduced the moisture content of the litter compared with pens without perches, because more manure overall could have fallen from the perching birds into the pit instead of on the litter. Moist and dirty litter is known to increase the risk of pododermatitis (Shepherd and Fairchild, 2010 and references therein). Litter quality was not assessed, so we cannot analyze the role of litter quality for pododermatitis, but this is a mechanism that should be considered for future work.

It is unclear why hens in pens with perches were lighter on average. Feed was distributed in the feed troughs passing through all pens as checked by the caretaker, so hens in all pens should have had equal access. Jumping up and down to reach the perch could possibly increase the energy expenditure of the hens, resulting in reduced body mass. The additional energy required for this activity might also explain why laying hens in cages with access to perches had lower abdominal fat pad weights (Jiang et al., 2014). In contrast



to this study, the addition of perches in broiler pens increased body mass (Velo and Ceular, 2016) or showed no consistent effects (Martrenchar et al., 2000; Su et al., 2000). The usage of perches could increase muscle mass, but since number, location, and usage of perches differed among studies, variable results are not surprising and further research is suggested (Velo and Ceular, 2016). Given the importance of body mass in terms of production efficiency and as an indication of physiological health, future research is needed to understand the underlying mechanisms between body mass and perch use.

Keel bone damage is a well-known and intensively studied area in laying hens (e.g., Sandilands et al., 2009; Wilkins et al., 2011; Käppeli et al., 2011a; Harlander-Matauschek et al., 2015; Heerkens et al., 2016), but to our knowledge keel bone fractures have not been documented in broiler breeders. In laying hens, falls from perches are thought to be a likely cause for keel bone damage (Stratmann et al., 2015; Campbell et al., 2016). Numerous falls were observed in Sasso broiler breeder hens in another experiment (unpublished data) and may provide a potential explanation. Some fell from the inoperative drinking line that was about 2 m above the litter. Keel bone fractures in laying hens also also be caused by pressure on the keel bone while perching (Pickel et al., 2010). The large breast muscle might protect the keel bones of broiler breeder hens to a certain degree, because the keel bone is less exposed in comparison to laying hens. Additionally, the lower prevalence of keel bone damage in broiler breeders might be due to less perching behavior than in laying hens. It was verified that the hens scored for keel bone damage were from the respective pen and had not switched pens during the experiment, though our method did not allow confirmation of whether they had actually used perches. While falling may provide a specific action for keel bone damage, high egg-laying rates causing calcium deficiencies are thought to weaken the (keel) bones and could leave hens susceptible to keel bone damage (Whitehead and Fleming, 2000). Similar to the egg-laying line, a high number of eggs is also a selection goal in female broiler breeders, which might favor weak bones and fractures. The rate of keel bone damage in the broiler breeders was low compared with rates of keel bone damage in layers. However, the breeders of layers also have a lower prevalence of keel bone damage than layers (Käppeli et al., 2011b). The laying rate of the broiler breeder hens in the present study (less than 60%) was much lower than the laying rates of Lohmann brown (86%) or Lohmann brown breeder stock (87.8%) in Käppeli et al. (2011b). Therefore, given relatively less egg production in broiler breeders and the suggestion that large amounts of calcium required for egg production lead to weakened bone (Whitehead and Fleming, 2000), it is not surprising that the prevalence of keel bone fractures was lower in the broiler breeders (20%) than Lohmann brown breeder stock (35%).

The percentage of perching birds at night was relatively low and declined with increasing age from about 50 to 20%. The reason for the low overall rate and change over time should be considered to determine the suitability of the provided perches. Possibly, the breeders had difficulties accessing the 50 cm high perches, a problem that could worsen as they got older and heavier. Ramps or other structures (e.g., lower perches) aiding in accessing the perches would be advisable. However, as chickens including broiler breeders strongly favor the highest structures (Schrader and Müller, 2009; Gebhardt-Henrich et al., 2014), this factor could have obscured the effect of perch length on perching behavior. For this reason, perches were offered at only one height in this study. If perches had been lower than 50 cm above the slats, the area underneath would not have counted as accessible area under Swiss legislation. However, lower perches might have been used to a greater extent. There are not many data on perch use by broiler breeders. The majority (up to 90%) of broiler breeders in single cages roosted on perches that were only 5 cm above the cage floor (Pearson, 1983). However, modern broiler breeders greatly differ from former strains (Zuidhof et al., 2014), so it is unclear if these studies can be compared. Perching behavior develops during ontogeny from mainly daytime perching to predominantly nighttime perching around 6 WOA (Heikkilä et al., 2006). Therefore, data on perching in broiler chickens that are often slaughtered at this age are difficult to compare with studies on breeders. Broilers use lower perches more than higher perches, but numbers of broilers on perches are generally low and platforms are preferred as roosting sites (Norrington et al., 2016; Kaukonen et al., 2017).

The low number of perching birds in our study might have yielded conservative estimates of effect sizes for the provisioning of perches. Additionally, the failure of identifying the perching behavior of individual birds and linking the frequency of perching with health differences of these birds lowered the power of the analyses. Individual markings were applied but were difficult to detect on videos, and low numbers of perching birds with marks prevented the analysis of individual perching behavior. Despite these limitations, this is the first study to demonstrate perching behavior of modern fast growing broiler breeders in a controlled experimental setting, and the results support national guidelines for the provision of perches in broiler breeders. Elevated surfaces like the slats served only as a less preferred alternative when perches were lacking or supplied in insufficient quantity. Thus, elevated slats did not fulfill the broiler breeders' need of perching to the same extent as aerial perches.

The main product of broiler breeders is the broiler chick. In our experiment, we found no influence of housing of the broiler breeders with perches on the broiler chicks and their growth rates. However, combining all perch treatments and low numbers of perching birds might have led to low power to detect differences.

In conclusion, broiler breeders used perches at night, suggesting the fulfillment of a behavioral need. Production was not impaired in pens with perches, though limited health benefits were identified, such as improved foot health, though the effect varied with body mass. The provision of 14 cm of perch length per bird seemed adequate because the number of perching birds did not increase when 20 cm were offered, but 10 cm would not be enough. The effects of perch length during rearing suggests that the provision of perches during rearing was important. Therefore, the provision of perches could enhance animal welfare of broiler breeders while ensuring high production.

## ACKNOWLEDGMENTS

This project was funded by the Federal Food Safety and Veterinary Office FSVO (2.13.10), Bell Schweiz AG, Micarna SA, and Wüthrich Brüterei AG. We thank Fritz Schwab for animal care of the broiler breeders and the staff of the Aviforum for animal care of the broilers. Maurice Sander (Aviagen™) gave valuable advice on the management of broiler breeders. We thank the extended Schwab family for hospitality on their farm during the study. Without numerous helpers, this project would not have been possible.

## REFERENCES

- Ahmed, A. A., W. Ma, Y. Ni, S. Wang, and R. Zhao. 2014. Corticosterone in ovo modifies aggressive behaviors and reproductive performances through alterations of the hypothalamic-pituitary-gonadal axis in the chicken. *Animal Reproduction Science*. doi: 10.1016/j.anireprosci.2014.02.013.
- Aviagen™. 2012. Mastelterniere Management Programm. Aviagen™.
- Babacanoglu, E., S. Yalçin, and S. Uysal. 2013. Evaluation of a stress model induced by dietary corticosterone supplementation in broiler breeders: Effects on egg yolk corticosterone concentration and biochemical blood parameters. *Brit. Poult. Sci.* 54:677–685.
- Brake, J. 1987. Influence of presence of perches during rearing on incidence of floor laying in broiler breeders. *Poult. Sci.* 66:1587–1589.
- Brake, J. 1998. Equipment design for breeding flocks. *Poult. Sci.* 77:1833–1841.
- Brake, J., T. Keeley, and R. B. Jones. 1994. Effect of age and presence of perches during rearing on tonic immobility fear reactions of broiler breeder pullets. *Poult. Sci.* 73:1470–1474.
- Campbell, D., S. L. Goodwin, M. M. Makagon, J. C. Swanson, and J. M. Siegford. 2016. Failed landings after laying hen flight in a commercial aviary over two flock cycles. *Poult. Sci.* 95:188–197.
- CEC. 1999. European Union Council Directive 1999/74/EC. Laying down minimum standards for the protection of laying hens.
- Damme, K. 1996. Voliersystem für Mastelterniere. Erste Erfahrungen sind vielversprechend. *DGS Magazin*. 96:10–17.
- Donaldson, C. J., M. E. E. Ball, and N. E. O'Connell. 2012. Aerial perches and free-range laying hens. The effect of access to aerial perches and of individual bird parameters on keel bone injuries in commercial free-range laying hens. *Poult. Sci.* 91:304–315.
- EFSA Panel on Animal Health and Welfare (AHAW). 2010. Scientific opinion on welfare aspects of the management and housing of the grand-parent and parent stocks raised and kept for breeding purposes. *EFSA Journal*. 8:1667.
- Gebhardt-Henrich, S. G., E. K. F. Fröhlich, M. J. Toscano, and H. Würbel. 2014. Die Benützung von erhöhten Sitzstangen und Volierenetagen bei Masteltern. Pages 127–135 in *Aktuelle Arbeiten zur artgemässen Tierhaltung*. M. Erhard, U. Pollmann, K. Reiter, and S. Waiblinger, eds., KTBL, Darmstadt.
- Groothuis, T. G. G., and H. Schwabl. 2008. Hormone-mediated maternal effects in birds: mechanisms matter but what do we know of them?, *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*. 363:1647–1661.
- Guibert, F., M.-A. Richard-Yris, S. Lumineau, K. Kotrschal, A. Bertin, C. Petton, E. Möstl, and C. Houdelier. 2011. Unpredictable mild stressors on laying females influence the composition of Japanese quail eggs and offspring's phenotype. *Appl. Anim. Behav. Sci.* 132:51–60.
- Harlander-Matauschek, A., T. B. Rodenburg, V. Sandilands, B. W. Tobalske, and M. J. Toscano. 2015. Causes of keel bone damage and their solutions in laying hens. *Worlds Poult. Sci. J.* 71:461–472.
- Heerkens, J. L. T., E. Delezie, B. Ampe, T. B. Rodenburg, and F. A. M. Tuytens. 2016. Ramps and hybrid effects on keel bone and foot pad disorders in modified aviaries for laying hens. *Poult. Sci.* doi: 10.3382/ps/pew157.
- Heikkilä, M., A. Wichman, S. Gunnarsson, and A. Valros. 2006. Development of perching behaviour in chicks reared in enriched environment. *Appl. Anim. Behav. Sci.* 99:145–156.
- Jiang, S., P. Y. Hester, J. Y. Hu, F. F. Yan, R. L. Dennis, and H. W. Cheng. 2014. Effect of perches on liver health of hens. *Poult. Sci.* 93:1618–1622.
- Jones, E., and N. B. Prescott. 2000. Visual cues used in the choice of mate by fowl and their potential importance for the breeder industry. *World's Poult. Sci. J.* 56:127–138.
- Käppeli, S., S. G. Gebhardt-Henrich, E. Fröhlich, A. Pfulg, H. Schaublin, and M. H. Stoffel. 2011b. Effects of housing, perches, genetics, and 25-hydroxycholecalciferol on keel bone deformities in laying hens. *Poult. Sci.* 90:1637–1644.
- Käppeli, S., S. G. Gebhardt-Henrich, E. Fröhlich, A. Pfulg, and M. H. Stoffel. 2011a. Prevalence of keel bone deformities in Swiss laying hens. *Brit. Poult. Sci.* 52:531–536.
- Karaca, A. G., H. M. Parker, J. B. Yeatman, and C. D. McDaniel. 2002. Role of seminal plasma in heat stress infertility of broiler breeder males. *Poult. Sci.* 81:1904–1909.
- Kaukonen, E., M. Norring, and A. Valros. 2016. Effect of litter quality on foot pad dermatitis, hock burns and breast blisters in broiler breeders during the production period. *Avian Pathol.* 45:667–673.
- 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. *Anim.* 11:864–871.
- Kiyama, Z., K. Küçükyılmaz, and A. Orojpour. 2016. Effects of perch availability on performance, carcass characteristics, and footpad lesions in broilers. *Arch. Anim. Breed.* 59:19–25.
- LeVan, N. F., I. Estevez, and W. Stricklin. 2000. Use of horizontal and angled perches by broiler chickens. *Appl. Anim. Behav. Sci.* 65:349–365.
- Mack, L. A., J. N. Felper-Gant, R. L. Dennis, and H. W. Cheng. 2013. Genetic variations alter production and behavioral responses following heat stress in 2 strains of laying hens. *Poult. Sci.* 92:285–294.
- Martrenchar, A., D. Huonnic, J. P. Cotte, E. Boilletot, and J. P. Morisse. 2000. Influence of stocking density, artificial dusk and group size on the perching behaviour of broilers. *Brit. Poult. Sci.* 41:125–130.
- Mashaly, M. M., G. L. Hendricks (3rd), M. A. Kalama, A. E. Gehad, A. O. Abbas, and P. H. Patterson. 2004. Effect of heat stress on production parameters and immune responses of commercial laying hens. *Poult. Sci.* 83:889–894.
- McDaniel, C. D., R. K. Bramwell, J. L. Wilson, and B. Howarth, Jr. 1995. Fertility of male and female broiler breeders following exposure to elevated ambient temperatures. *Poult. Sci.* 74:1029–1038.
- Moyle, J. R., D. E. Yoho, R. S. Harper, and R. K. Bramwell. 2010. Mating behavior in commercial broiler breeders: Female effects. *J. Appl. Poult. Res.* 19:24–29.
- Muiruri, H. K., P. C. Harrison, and H. W. Gonyou. 1990. Preferences of hens for shape and size of roosts. *Appl. Anim. Behav. Sci.* 27:141–147.

- Nakagawa, S., and H. Schielzeth. 2010. Repeatability for Gaussian and non-Gaussian data: A practical guide for biologists. *Biol. Rev. Camb. Philos.* 85:935–956.
- Newberry, R. C., I. Estevez, and L. J. Keeling. 2001. Group size and perching behaviour in young domestic fowl. *Appl. Anim. Behav. Sci.* 73:117–129.
- Norring, M., E. Kaukonen, and A. Valros. 2016. The use of perches and platforms by broiler chickens. *Appl. Anim. Behav. Sci.* 184:91–96.
- Olsson, I. A. S., and L. J. Keeling. 2000. Night-time roosting in laying hens and the effect of thwarting access to perches. *Appl. Anim. Behav. Sci.* 68:243–256.
- Olsson, I. A., and L. J. Keeling. 2002. The push-door for measuring motivation in hens. Laying hens are motivated to perch at night. *Anim. Welf.* 11:11–19.
- Pearson, R. A. 1983. Prevention of foot lesions in broiler breeder hens kept in individual cages. *Brit. Poult. Sci.* 24:183–190.
- Pereira, D. F., A. Nääs, D. A. Salgado, C. R. Gaspar, C. A. Bighi, and N. L. Penha. 2007. Correlations among behavior, performance and environment in broiler breeders using multivariate analysis. *Rev. Bras. Cienc. Avic.* 9. doi: 10.1590/S1516-635X2007000400001.
- Pickel, T., B. Scholz, and L. Schrader. 2010. Perch material and diameter affects particular perching behaviours in laying hens. *Appl. Anim. Behav. Sci.* 127:37–42.
- Sandilands, V., C. Moinard, and N. H. C. Sparks. 2009. Providing laying hens with perches. Fulfilling behavioural needs but causing injury? *Br. Poult. Sci.* 50:395–406.
- Sas, B., G. Domány, I. Gyimóthy, K. G. Kovácsné, and M. Süth. 2006. Influence of the type of management system on corticosterone transfer into eggs in laying hens. *Acta Vet. Hung.* 54:343–352.
- Scholz, B., S. Rönchen, H. Harmann, M. Hewicker-Trautwein, and O. Distl. 2008. Keel bone condition in laying hens. A histological evaluation of macroscopically assessed keel bones. *Berl Munch Tierarztl Wochenschr.* 121:89–94.
- Schrader, L., and B. Müller. 2009. Night-time roosting in the domestic fowl. The height matters. *Appl. Anim. Behav. Sci.* 121:179–183.
- Schrider, D. 2007. Selecting for Egg Production. [https://livestockconservancy.org/images/uploads/docs/ALBCchicken\\_assessment-2.pdf](https://livestockconservancy.org/images/uploads/docs/ALBCchicken_assessment-2.pdf). Last retrieved on August 23, 2016.
- Shepherd, E. M., and B. D. Fairchild. 2010. Footpad dermatitis in poultry. *Poult. Sci.* 89:2043–2051. doi: 10.3382/ps.2010-00770.
- Stratmann, A., E. K. Fröhlich, S. G. Gebhardt-Henrich, A. Harlander-Matauschek, H. Würbel, and M. J. Toscano. 2015. Modification of aviary design reduces incidence of falls, collisions and keel bone damage in laying hens. *Appl. Anim. Behav. Sci.* 165:112–123.
- Su, G., P. Sorensen, and S. C. Kestin. 2000. A note on the effects of perches and litter substrate on leg weakness in broiler chickens. *Poult. Sci.* 79:1259–1263.
- Tauson, R., and P. Abrahamsson. 1996. Foot and keel bone disorders in laying hens. Effects of artificial perch material and hybrid. *Acta Agric. Scand. Sect. A, Anim. Sci.* 46:239–246.
- TSchV. 2008. Tierschutzverordnung CH.
- Tuytens, F. A., M. Sprenger, A. van Nuffel, W. Maertens, and S. van Dongen. 2009. Reliability of categorical versus continuous scoring of welfare indicators: Lameness in cows as a case study. *Anim. Welf.* 18:399–405.
- Velo, R., and A. Ceular. 2016. Effects of stocking density, light and perches on broiler growth. *Anim. Sci. J. = Nihon chikusan Gakkaiho.* doi: 10.1111/asj.12630.
- Welfare Quality. 2009. Assessment protocol for poultry. Welfare Quality<sup>®</sup>; NEN, Lelystad, Netherlands, [Delft].
- Whitehead, C. C., and R. H. Fleming. 2000. Osteoporosis in cage layers. *Poult. Sci.* 79:1033–1041.
- Wilkins, L. J., J. L. McKinstry, N. C. Avery, T. G. Knowles, S. N. Brown, J. Tarlton, and C. J. Nicol. 2011. Influence of housing system and design on bone strength and keel bone fractures in laying hens. *Vet. Rec.* 169:414.
- Xie, J., L. Tang, L. Lu, L. Zhang, X. Lin, H.-C. Liu, J. Odle, and X. Luo. 2015. Effects of acute and chronic heat stress on plasma metabolites, hormones and oxidant status in restrictedly fed broiler breeders. *Poult. Sci.* 94:1635–1644.
- 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.