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Foot pad health in Lohmann Selected Leghorn and Lohmann Brown laying hens kept in different housing systems with modified perch design

Fußballenstatus von Lohmann Selected Leghorn und Lohmann Brown Legehennen in unterschiedlichen Haltungssystemen mit modifizierter Sitzstangenposition

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Introduction

Small group housing systems are being developed to improve animal welfare, to retain high egg production standards and to meet German and EU legislation. An advanced type of small group housing system is the modified small group housing system, which is equipped with perches at different levels. The objective of the present study was to evaluate if foot pad status of different layer lines was influenced by differences in perch design. The occurrence of pathological alterations of laying hens' foot pads is affected by different factors like housing system, stocking density, birds' genetics and perch design (Tauson and Abrahamsson, 1994). Skin reacts to mechanical and thermal stimuli. Several external influences lead to an adaptation of the skin's thickness (Liebich et al., 2004). Proliferative foot pad hyperkeratosis in poultry occurs as a consequence of adaptation growth caused by long-time or repeated exposure to pressure (Dämmrich and Loppnow, 1990). In laying hens, floor surfaces or perches can cause a non-physiological pressure load to layers' feet, which can result in skin proliferation (Siegwart, 1991; Keutgen et al., 1999; Weitzenbürger et al., 2005). While hyperkeratosis is a main finding in layers kept in cage systems (Abrahamsson and Tauson, 1993), epithelial lesions often occur in alternative housing systems, caused by contact to litter, excrements and use of perches (Keutgen et al., 1999; Wang et al., 1998). Foot pad lesion or so called pododermatitis is a form of contact dermatitis. First, hyperplasia and erosion of epidermis can be observed in histological analysis. This can progress rapidly to ulceration if unfavourable environmental conditions persist (Randall and Reece, 1996).

Materials and Methods

Housing systems

The three housing systems tested were installed in three separate rooms within the same experimental building. All systems were provided by Big Dutchman, Vechta, Germany. Housing systems included a modified small group housing system (Eurovent (EV) 625a-EU (MSG), a small group housing system (EV 625a-EU (SG)), a modified furnished cage system (EV 625A-EU (MFC) and two differently furnished cage systems (EV 625A-EU (FC), Aviplus (AP)). All housing systems tested were built over four tiers. Hens were kept in groups of 40 and 60 layers in EV 625a-EU (MSG and SG with a ground floor area of 2412 x 1250 mm), 20 and 30 in EV 625A-EU (MFC and FC with a ground floor size of 2412 x 624 mm) and 10 and 20 hens per compartment in Aviplus (AP with a ground floor size of 1206 x 625 mm). Although group sizes differed, compartment height (450–525 mm) and space per hen (750 mm) were identical for all compartments in the different housing systems. FC, MFC and AP were arranged double sided, whereas SG and MSG were built without centre partition. Compartments were equipped with a sloping wire floor and were furnished with perches, nest boxes (Astroturf, Aviplus or Netlon mats), dust baths and claw abrasion devices (abrasive blocks, perforated metal plates or two abrasive blocks (AP); abrasive blocks (SG, MSG); adhesive stripes (FC, MFC). Dust baths in AP were temporarily accessible for hens. In the other housing systems evaluated, dust baths were equipped with Astroturf, Aviplus or Netlon mats and were accessible throughout the day. Dust bathing substrate (wood shavings, Ø 2-3 mm) was offered automatically once a day.

Perch positions and perch design

Two perches were installed in FC, MFC and AP and four perches in SG and MSG. In addition, the supply pipe (Ø 45 mm, galvanised zinc) for dust bathing substrate in the centre of SG- and MSG-compartments was also useable for perching (fifth perching-opportunity). In all housing systems evaluated, each hen was offered 15 cm perch-length of its disposal. Perches were installed in parallel position to the front of the cage. In AP, FC and MFC, only white plastic perches (oval/rectangular profile, flat up- and under site, riffles on the front- and backside) in a height of 90 mm were installed in both trials. A certain percentage of SG-compartments were modified to MSG-compartments by installing perches at different heights. Elevated perch positions in the system tested comprised the front perch being elevated (FE), the back perch being heightened (BE) or both perches being heightened and arranged in a stepped position (ST). In the first trial, MSG-compartments were equipped with front perches (plastic on an even level) and elevated round metal back perches (BE) in a height of 200 mm (distance to cage floor). In the

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second trial, compartments with FE-, BE- and ST-perches were compared. In ST-compartments of MSG, only metal perches were used. They were installed in a distance of 200 and 275 mm to the cage floor. Detailed information for the different housing systems and their equipment is available at the website of Big Dutchman (http://www.kleinvoliere.de/).

Layer lines, feeding and management

Two trials were included in the present study. In the first trial, comprising the period August 2004 to August 2005, Lohmann Brown (LB) and Lohmann Selected Leghorn (LSL) laying hens were kept to equal parts. In the second trial, lasting from October 2005 to October 2006, only LSL hens were used. A number of approximately 2,880 hens were kept per housing system (EV 625a-EU, EV 625A-EU, AP) and trial. All hens were reared in cages until the age of 18 weeks and then transferred to the three different housing systems for laying hens. Ad libitum feeding was automatically provided three to four times a day and water was supplied ad libitum per nipple drinkers. The lighting period was gradually stepped up to 14 hrs per day. Management conditions were identical in both trials.

Macroscopic foot pad evaluation

Examinations of foot pad health were performed in both trials at an age of 24 (6^{th} laying month) and 30 months (12^{th} laying month). Per month, 144 layers were randomly chosen out of the different housing systems considering layer line, group size and perch position (Table 1). Foot pad status was evaluated in a total of 576 hens (144 LSL, 144 LB in the first trial and 288 LSL in the second trial). The occurrence of hyperkeratosis and lesions was assessed and classified due to severity on a scale from 1 (no hyperkeratosis) to 5 (very severe hyperkeratosis) and from 1 (no lesion, no swelling of foot pad) to 4 (deep and large epithelial lesion and high grade swelling of foot pad) (Table 2). Both feet per hen were examined and severity rating was applied according to the most distinctive alteration. Findings were evaluated separately for sole pad, toe pad and the region between toe and claw.

Table 1. Number of laying hens examined with regard to layer line and perch position within the different housing systems Aviplus, Eurovent 625A-EU and Eurovent 625a-EU
Anzahl der untersuchten Legehennen unter Berücksichtigung von Legelinie und Sitzstangenposition in den Haltungssystemen Aviplus, Eurovent 625A-EU and Eurovent 625a-EU

Housing system		Layer line (trial)		
		LSL (1)	LB (1)	LSL (2)
Aviplus	AP NE	48	48	96
Eurovent 625A-EU	FC NE	28	28	56
	MFC BE	8	8	16
	MFC FE	12	12	24
Eurovent 625a-EU	SG NE	32	32	n/a
	MSG BE	16	16	32
	MSG ST	n/a	n/a	32
	MSG FE	n/a	n/a	32

LSL = Lohmann Selected Leghorn; LB = Lohmann Brown; NE = non-elevated perch(es); BE = elevated back perch(es); FE = elevated front perch(es); ST = stepped perches; AP = furnished cage system Aviplus; FC (MFC) = furnished cage system (modified furnished cage system) Eurovent 625A-EU; SG (MSG) = small group housing system (modified small group housing system) Eurovent 625a-EU; n/a = not available.

Histological foot pad evaluation

Skin biopsy samples of sole and toe pads (alternating right or left foot) were taken during the first trial from every second laying hen after macroscopic examination. Regardless of macroscopic alterations, samples were taken from the centre of the sole pad and the centre of the middle toe pad. This sampling area was chosen for histological analysis because of its exposure to mechanical stimulus while perching or standing on wire floor. Skin biopsy samples were fixed in 10% buffered formalin (min. 24 h), embedded in paraffin wax and cut into histological slices (2 µm) with a rotation microtome (Reichert-Jung 2030 Biocut, Bensheim, Germany). Slices were stained with Haemalaun-Eosin (H.E.). Sole pad samples of 69 hens and toe pad samples of 68 layers (approximately 12 hens per laying month and housing system) were chosen for examination. Histological evaluation was performed using a light-optical microscope (Dialux 20 EB, Leitz, Wetzlar, Germany). The histopathological traits hyperkeratosis, acanthosis, elongation of rete folds, development of secondary papillae, erosion, ulceration, cellular infiltration and bacterial colonisation of epidermal surface were reported. Hyperkeratosis and cellular infiltration were classified using a scoring scheme from 1 (normal) to 4 (severe) while the other traits examined were recorded as binary traits.

Statistical analysis

Statistical analysis of macroscopic foot pad status was performed using the MIXED procedure of SAS, version 9.1.3. (Statistical Analysis System Institute Inc., Cary, NC, USA 2006). For both trials, the fixed effects of housing

Table 2. Classification of macroscopic alterations in foot pads
Klassifizierung der makroskopischen Fußballenbefunde

Severity rating	Macroscopic findings of hyperkeratosis (1-5)	Macroscopic findings of lesions (1-4)
1	no hyperkeratosis	intact epithelium, no swelling of foot pad
2	mild hyperkeratosis	superficial lesion of the epithelium, no swelling of foot pads
3	moderate hyperkeratosis	deep epithelial lesions and/or swelling of foot pad
4	severe hyperkeratosis	deep and large epithelial lesions, high-graded swelling of foot pad
5	very severe hyperkeratosis	–

system, group size, layer line (first trial) laying month and perch position were included in the statistical model. In trial 1, the fixed effect of perch position within housing system and layer line was significant for the trait hyperkeratosis within the region between toe and claw in the analysis of variance ($p < 0.01$). Each compartment of the different housing systems was treated as a randomly distributed effect. Layers' body weight (in the first trial within layer line) was used as a linear covariate (Table 5).

Statistical model for macroscopic foot pad status in trial 1:

$$Y_{ijklmnop} = \mu + SYS_i + LIN_j + SYS * LIN_{ij} + GR(SYS)_{ik} + MON_l + PER(SYS)_{im} + b \times BW(LIN)_{jn} + comp(SYS)_{io} + e_{ijklmnop}$$

$Y_{ijklmnop}$:	score for macroscopically determined alterations of sole pad, toe pad and the region between toe and claw (except sole pad lesion, toe pad hyperkeratosis and hyperkeratosis between toe and claw)
μ:	model constant
SYS_i:	fixed effect of housing system (i = 1 to 3)
LIN_j	fixed effect of layer line (j = 1 to2)
$SYS * LIN_{ij}$:	interaction between housing system and laying line
$GR(SYS)_{ik}$:	fixed effect of group size within housing system (k = 1 to 5)
MON_l:	fixed effect of laying month (l = 1 to 2)
$PER(SYS)_{im}$:	fixed effect of perch position within housing system (m = 1 to 4)
$BW(LIN)_{jn}$:	body weight within layer line
$comp(SYS)_{io}$:	random effect of compartment within housing system (o = 91)
b:	linear regression
$e_{ijklmnop}$:	random error coefficient

For some traits, modifications of the model mentioned above had to be made in order to regard significant interactions which were not significant for the other traits. The three-way interaction between housing system, layer line and laying month was added for the trait sole pad lesion. The two-way interaction between layer line and laying month was included for the trait toe pad hyperkeratosis. The fixed effect of perch position (NE, BE, ST, FE) and the random effect of individual compartment within housing system were nested within housing system and layer line for the trait hyperkeratosis between toe and claw. We employed a linear model because residuals were normally distributed using the NORMAL function of the UNIVARIATE SAS-procedure.

Statistical model for macroscopic foot pad status in trial 2:

$$Y_{ijklmno} = \mu + SYS_i + GR(SYS)_{ij} + MON_k + PER(SYS)_{il} + b \times BW_m + comp(SYS)_{in} + e_{ijklmno}$$

$Y_{ijklmno}$:	score for macroscopically determined alterations of sole pad, toe pad and the region between toe and claw (except the trait lesion in the region between toe and claw)
μ:	model constant
SYS_i:	fixed effect of housing system (i = 1 to 3)
$GR(SYS)_{ij}$:	fixed effect of group size within housing system (j = 1 to 5)
MON_k:	fixed effect of laying month (k = 1 to 2)
$PER(SYS)_{il}$:	fixed effect of perch position (l = 1 to 7)
BW_m:	body weight
$comp(SYS)_{in}$:	random effect of compartment of housing system (n = 84)
b:	linear regression
$e_{ijklmno}$:	random error coefficient

The two-way interaction between housing system and laying month was significant for the severity of lesions within the region between toe and claw. Therefore, this interaction had to be included in the statistical model for this trait. With respect to the different claw shortening devices in AP, an extended statistical model (both trials) was applied to evaluate possible significant differences.

Results

Macroscopic foot pad evaluation

Results of macroscopic foot pad evaluation in trial 1 revealed that mild hyperkeratosis (score = 2) of sole pad, toe pad and the region between toe and claw was the most frequently observed finding in hens of all housing systems. Moderate sole pad hyperkeratosis (score = 3) mostly occurred in layers housed in compartments with elevated back perches (BE) in MSG (12.5%). In AP and compartments of MFC with elevated front perches (FE), moderate sole pad hyperkeratosis could not be detected. The highest incidence of moderate toe pad hyperkeratosis was found in hens kept in BE-compartments of MFC (25.0%). The region between toe and claw was affected by moderate hyperkeratosis in 38.5% of layers housed in AP. Severe hyperkeratosis between toe and claw (score = 4) was mostly observed in hens kept in BE-compartments of MFC (12.5%). The highest incidence of superficial sole pad lesions (score = 2) occurred in hens kept in BE-compartments of MFC and MSG (both 37.5%). Deep epithelial lesions and/or swelling of sole pads (score = 3) occurred in 21.9% of hens in compartments of SG, followed by hens kept in BE-compartments of MSG and in FC to equal parts (12.5%). Except of hens housed in BE-compartments of MSG and MFC, more than 50% of layers were affected by superficial toe pad lesions. The highest incidence of superficial lesions between toe and claw was found in MFC (25.0%), if compartments were equipped with BE-perches. Like in trial 1, mild hyperkeratosis was the most frequent finding in sole pads, toe pads and within the region between toe and claw in all housing systems tested in trial 2. Furthermore, the highest incidence of moderate sole pad hyperkeratosis was also observed in MSG-BE-compartments (9.4%). Similar to trial 1, moderate sole pad hyperkeratosis did not occur in AP and FE-compartments of MFC. Furthermore, moderate hyperkeratotic sole pad alterations were not detected in FE-compartments of MSG and BE-compartments of MFC. While in trial 1 the highest incidence of moderate toe pad hyperkeratosis was found in BE-compartments of MFC, only layers kept in FE-compartments of MFC were affected by moderate alterations in trial 2 (4.2%). Moderate hyperkeratosis within the region between toe and claw was mostly found in AP (14.6%), but obviously less frequent compared to layers kept in AP during trial 1 (38.5%). Superficial sole pad lesions mostly occurred in FE-compartments of MFC (25.0%). Similar to trial 1, deep epithelial lesions and/or swelling of sole pads could mostly be observed in layers housed in BE-compartments of MSG (31.3%), followed by FC and FE-compartments of MFC and MSG to equal numbers (25.0%). Superficial toe pad lesions mainly occurred in FE-compartments of MFC (62.5%). While in trial 1 an equal number of hens kept in AP and FE-compartments of MFC showed such alterations, layers housed in AP during trial 2 were less affected (43.8%). Deep epithelial lesions and/or swelling of toe pads were predominantly observed in compartments with 'stepped' (ST) perches in MSG (15.6%). Superficial lesions in the region between toe and claw were predominantly found in AP (27.1%).

This was in contrast to trial 1, where the highest incidence was found in layers kept in BE-compartments of MFC. While in trial 1 only few laying hens were affected by deep epithelial lesions and/or swelling within the region between toe and claw, in trial 2, 12.5% of hens housed in BE-compartments of MFC and 12.5% of layers kept in MSG (BE, ST, FE) showed alterations in this particular region.

Distribution of foot pad status scorings for the different foot regions and mean values for the different housing systems and in total are shown in Tables 3 and 4.

Analyses of variance

Analyses of variance revealed that foot pad status was significantly influenced by housing system (Table 5). In both trials, a significant influence of housing system was obvious for the traits hyperkeratosis and lesions of sole pads and on hyperkeratosis between toe and claw. Perch position within housing system was significant for sole pad hyperkeratosis in the first and sole pad lesions in the second trial.

Table 3. Distribution of individual scores of foot pad status (%), mean scores ($\bar{x}$) and standard deviations (s) in laying hens kept in the different housing systems with different perch position during trial 1
Verteilung der Bewertungen des Fußballenstatus (%), Mittelwerte ($\bar{x}$) und Standardabweichungen (s) für die Legehennen in den verschiedenen Haltungssystemen im Legedurchgang 1

System	Score	Hyperkeratosis sole pad	Hyperkeratosis toe pad	Hyperkeratosis toe/claw	Lesion sole pad	Lesion toe pad	Lesion toe/claw
AP NE	1	20.8	5.2	1.0	79.2	39.6	87.5
	2	79.2	81.3	54.2	14.6	58.3*	11.5
	3	–	13.5	38.5	5.2	2.1	1.0
	4	–	–	6.3	1.0	–	–
	$\bar{x} \pm s$	1.79 ± 0.41	2.08 ± 0.43	2.50 ± 0.63	1.28 ± 0.61	1.63 ± 0.53	1.14 ± 0.37
FC NE	1	3.6	1.8	–	62.5	41.1	80.4
	2	91.1	89.3	83.9	25.0	53.6	19.6
	3	5.4	7.1	16.1	12.5	3.6	–
	4	–	1.8	–	–	1.8	–
	$\bar{x} \pm s$	2.02 ± 0.30	2.09 ± 0.39	2.16 ± 0.37	1.50 ± 0.71	1.66 ± 0.64	1.20 ± 0.40
MFC BE	1	18.8	6.3	12.5	56.3	50.0	75.0
	2	75.0	68.8	62.5	37.5	43.8	25.0
	3	6.3	25.0	12.5	6.3	6.3	–
	4	–	–	12.5	–	–	–
	$\bar{x} \pm s$	1.88 ± 0.50	2.19 ± 0.54	2.25 ± 0.86	1.50 ± 0.63	1.56 ± 0.63	1.25 ± 0.45
MFC FE	1	25.0	16.7	20.8	62.5	41.7	95.8
	2	75.0	75.0	70.8	25.0	58.3	4.2
	3	–	8.3	8.3	8.3	–	–
	4	–	–	–	4.2	–	–
	$\bar{x} \pm s$	1.75 ± 0.44	1.92 ± 0.50	1.88 ± 0.54	1.54 ± 0.83	1.58 ± 0.50	1.04 ± 0.20
SG NE	1	3.1	–	–	57.8	46.9	85.9
	2	93.8	87.5	81.3	20.3	51.6	12.5
	3	3.1	10.9	15.6	21.9	1.6	1.6
	4	–	1.6	3.1	–	–	–
	$\bar{x} \pm s$	2.00 ± 0.25	2.14 ± 0.39	2.22 ± 0.49	1.64 ± 0.82	1.55 ± 0.53	1.16 ± 0.41
MSG BE	1	15.6	6.3	–	50.0	59.4	78.1
	2	71.9	81.3	84.4	37.5	34.4	18.8
	3	12.5	12.5	15.6	12.5	3.1	3.1
	4	–	–	–	–	3.1	–
	$\bar{x} \pm s$	1.97 ± 0.54	2.06 ± 0.44	2.16 ± 0.37	1.63 ± 0.71	1.50 ± 0.72	1.25 ± 0.51
Total	$\bar{x} \pm s$	1.90 ± 0.40	2.09 ± 0.43	2.27 ± 0.57	1.48 ± 0.72	1.59 ± 0.58	1.16 ± 0.40

NE = non-elevated perch(es); BE = elevated back perch(es); FE = elevated front perch(es); AP = furnished cage system Aviplus; FC (MFC) = furnished cage system (modified furnished cage system) Eurovent 625A-EU; SG (MSG) = small group housing system (modified small group housing system) Eurovent 625a-EU.
* The highest frequency of the highest grading of a single criterion of the foot pad status in the housing system examined is underlined.

Table 4. Distribution of individual scores of foot pad status (%), mean scores ($\bar{x}$) and standard deviations (s) in laying hens kept in the different housing systems with different perch position during trial 2
Verteilung der Bewertungen des Fußballenstatus (%), Mittelwerte ($\bar{x}$) und Standardabweichungen (s) für die Legehennen in den verschiedenen Haltungssystemen im Legedurchgang 2

System	Score	Hyperkeratosis sole pad	Hyperkeratosis toe pad	Hyperkeratosis toe/claw	Lesion sole pad	Lesion toe pad	Lesion toe/claw
AP NE	1	29.2	13.5	3.1	78.1	54.2	63.5
	2	70.8	86.5	79.2	10.4	43.8	27.1
	3	–	–	14.6*	8.3	2.1	7.3
	4	–	–	3.1	3.1	–	2.1
	$\bar{x} \pm s$	1.71 ± 0.46	1.86 ± 0.34	2.18 ± 0.52	1.36 ± 0.77	1.48 ± 0.54	1.48 ± 0.73
FC NE	1	19.6	7.1	5.4	50.0	57.1	69.6
	2	75.0	92.9	83.9	17.9	39.3	19.6
	3	5.4	–	5.4	25.0	3.6	8.9
	4	–	–	5.4	7.1	–	1.8
	$\bar{x} \pm s$	1.86 ± 0.48	1.93 ± 0.26	2.11 ± 0.56	1.89 ± 1.02	1.46 ± 0.57	1.43 ± 0.74
MFC BE	1	31.3	12.5	12.5	75.0	56.3	68.8
	2	68.8	87.5	75.0	18.8	43.8	18.8
	3	–	–	12.5	6.3	–	12.5
	4	–	–	–	–	–	–
	$\bar{x} \pm s$	1.69 ± 0.48	1.88 ± 0.34	2.00 ± 0.52	1.31 ± 0.60	1.44 ± 0.51	1.44 ± 0.73
MFC FE	1	25.0	12.5	16.7	45.8	37.5	79.2
	2	75.0	83.3	83.3	25.0	62.5	8.3
	3	–	4.2	–	25.0	–	8.3
	4	–	–	–	4.2	–	4.2
	$\bar{x} \pm s$	1.75 ± 0.44	1.92 ± 0.41	1.83 ± 0.38	1.88 ± 0.95	1.63 ± 0.49	1.38 ± 0.82
MSG BE	1	12.5	3.1	3.1	40.6	56.3	59.4
	2	75.0	96.9	93.8	21.9	40.6	25.0
	3	9.4	–	3.1	31.3	–	12.5
	4	3.1	–	–	6.3	3.1	3.1
	$\bar{x} \pm s$	2.03 ± 0.59	1.97 ± 0.18	2.00 ± 0.25	2.03 ± 1.00	1.50 ± 0.67	1.59 ± 0.84
MSG ST	1	15.6	15.6	3.1	65.6	62.5	65.6
	2	78.1	84.4	90.6	15.6	21.9	21.9
	3	6.3	–	3.1	12.5	15.6	12.5
	4	–	–	3.1	6.3	–	–
	$\bar{x} \pm s$	1.91 ± 0.47	1.84 ± 0.37	2.06 ± 0.44	1.59 ± 0.95	1.53 ± 0.76	1.47 ± 0.72
MSG FE	1	9.4	15.6	6.3	43.8	67.7	78.1
	2	90.6	84.4	90.6	18.8	25.8	9.4
	3	–	–	3.1	25.0	6.5	12.5
	4	–	–	–	12.5	–	–
	$\bar{x} \pm s$	1.91 ± 0.30	1.84 ± 0.37	1.97 ± 0.31	2.06 ± 1.11	1.39 ± 0.62	1.34 ± 0.70
Total	$\bar{x} \pm s$	1.82 ± 0.47	1.89 ± 0.33	2.07 ± 0.47	1.68 ± 0.95	1.48 ± 0.59	1.45 ± 0.74

NE = non-elevated perch(es); BE = elevated back perch(es); FE = elevated front perch(es); ST = stepped perches; AP = furnished cage system Aviplus; FC (MFC) = furnished cage system (modified furnished cage system) Eurovent 625A-EU; SG (MSG) = small group housing system (modified small group housing system) Eurovent 625a-EU.
* The highest frequency of the highest grading of a single criterion of the foot pad status in the housing system examined is underlined.

Least square means for housing system and perch position

In trial 1, sole pad hyperkeratosis was significantly more severe in layers housed in EV 625a-EU (SG and MSG) compared to hens kept in AP. Sole pad lesions were significantly less distinctive in laying hens housed in AP compared to the other housing systems evaluated. Hyperkeratosis within the region between toe and claw was significantly less severe in laying hens housed within EV 625a-EU and EV 625A-EU (FC and MFC) in comparison to hens kept in AP (Table 6). Group size within EV 625A-EU had a significant influence on sole pad lesions. Layers housed in compart-

Table 5. Results of analyses of variance for housing system and perch position within housing system of foot pad status in trials 1 and 2
Ergebnisse der Varianzanalyse des Fußballenstatus für das Haltungssystem und die Sitzstangenposition innerhalb des Haltungssystems in den Legedurchgängen 1 und 2

Trait	Housing system			Perch position within housing system		
	DF	F	P	DF	F	P
Trial 1						
Hyperkeratosis sole pad	2	6.20	0.003	3	3.06	0.030
Lesion sole pad	2	8.39	< 0.001	3	0.05	0.983
Hyperkeratosis toe pad	2	0.24	0.788	3	1.85	0.140
Lesion toe pad	2	0.33	0.721	3	0.29	0.836
Hyperkeratosis toe/claw	2	15.12	< 0.001	–	–	–
Lesion toe/claw	2	0.61	0.543	3	1.53	0.209
Trial 2						
Hyperkeratosis sole pad	2	6.10	0.003	4	0.79	0.532
Lesion sole pad	2	7.21	<0.001	4	2.55	0.041
Hyperkeratosis toe pad	2	0.21	0.808	4	0.74	0.565
Lesion toe pad	2	0.05	0.947	4	0.58	0.675
Hyperkeratosis toe/claw	2	4.55	0.012	4	1.52	0.198
Lesion toe/claw	2	0.32	0.726	4	0.32	0.863

Table 6. Least square means (LSM) with their standard errors for foot pad scores for the different housing systems and their error probabilities (P) for the differences among housing systems in trials 1 and 2
LS-Mittelwerte (LSM), deren Standardfehler für die Fußballenbeurteilung in den verschiedenen Haltungssystemen sowie Irrtumswahrscheinlichkeiten (P) für Unterschiede zwischen den verschiedenen Haltungssystemen in den Legedurchgängen 1 und 2

Trait	Aviplus (AP) (I)	EV 625A (FC + MFC) (II)	EV 625a (SG + MSG) (III)	P		
				I-II	I-III	II-III
Trial 1						
Hyperkeratosis sole pad	1.79 ± 0.05	1.89 ± 0.05	2.00 ± 0.04	0.127	< 0.001	0.067
Lesion sole pad	1.24 ± 0.08	1.49 ± 0.09	1.66 ± 0.08	0.019	< 0.001	0.123
Hyperkeratosis toe/claw	2.51 ± 0.06	2.10 ± 0.06	2.20 ± 0.06	< 0.001	< 0.001	0.209
Trial 2						
Hyperkeratosis sole pad	1.71 ± 0.05	1.76 ± 0.06	1.95 ± 0.05	0.550	0.001	0.015
Lesion sole pad	1.39 ± 0.10	1.66 ± 0.11	1.91 ± 0.10	0.069	< 0.001	0.097
Hyperkeratosis toe/claw	2.18 ± 0.05	1.98 ± 0.06	2.01 ± 0.05	0.007	0.016	0.633

EV 625A = Eurovent 625A-EU; EV 625a = Eurovent 625a-EU; FC = furnished cages; MFC = modified furnished cages; SG = small group housing system; MSG = modified small group housing system.

ments with 30 hens were less affected than layers kept in groups of 20 hens. Within EV 625a-EU, hens in groups of 40 layers revealed significantly more distinctive sole pad hyperkeratosis than layers in compartments of 60 hens. Body weight within layer line showed a significant influence on the traits sole and toe pad lesions. Heavier hens of both layer lines were more severely affected by sole pad lesions. LB hens with a higher body weight also showed more severe toe pad lesions. The separate statistical model including the different claw shortening devices in AP revealed a significant influence on sole pad hyperkeratosis. Laying hens in compartments equipped with perforated metal plates were more severely affected by sole pad hyperkeratosis than layers kept in compartments with abrasive blocks. Different perch designs in FC and MFC had a significant influence on foot pad status. Sole pad hyperkeratosis was significantly more severe in layers housed in FC in comparison to hens kept in FE-compartments of MFC. Significantly higher scores for toe pad hyperkeratosis were observed in BE-compartments of MFC compared to FE-compartments of MFC. LSL layers kept in FC were significantly more severely affected by hyperkeratotic alterations in the region between toe and claw compared to LSL layers housed in FE-compartments of MFC. In LB layers, hyperkeratosis between toe and claw was significantly highest scored in laying hens housed in BE-compartments of MFC (Table 7). Different perch design in EV 625a-EU (SG and MSG) showed no significant influence on foot pad status. Like in trial 1, laying hens kept in EV 625a-EU (SG and MSG) during trial 2 were more severely affected by sole pad hyperkeratosis compared to layers housed in AP. Furthermore, the difference between EV

Table 7. Least square means (LSM) with their standard errors for foot pad scores for the different perch positions in Eurovent 625A-EU and their error probabilities (P) for the differences among different perch positions during trials 1 and 2
LS-Mittelwerte (LSM), deren Standardfehler für die Fußballenbeurteilung hinsichtlich der Sitzstangenposition im Haltungssystem Eurovent 625A-EU, sowie Irrtumswahrscheinlichkeiten (P) für Unterschiede zwischen den Sitzstangenpositionen in den Legedurchgängen 1 und 2

Trait	LL	FC NE (I)	MFC BE (II)	MFC FE (III)	P		
					I-II	I-III	II-III
Trial 1							
Hyperkeratosis sole pad		2.03 ± 0.05	1.87 ± 0.10	1.75 ± 0.08	0.156	0.004	0.343
Hyperkeratosis toe pad		2.08 ± 0.06	2.17 ± 0.10	1.91 ± 0.08	0.421	0.078	0.042
Hyperkeratosis toe/claw	LSL	2.16 ± 0.10	1.80 ± 0.18	1.79 ± 0.15	0.074	0.034	0.966
	LB	2.19 ± 0.10	2.70 ± 0.18	1.97 ± 0.15	0.012	0.218	0.002
Trial 2							
Lesion sole pad		1.87 ± 0.13	1.28 ± 0.24	1.83 ± 0.20	0.031	0.866	0.076
Hyperkeratosis toe/claw		2.10 ± 0.06	2.00 ± 0.12	1.83 ± 0.10	0.432	0.020	0.283

LL = Layer line; LB = Lohmann Brown; LSL = Lohmann Selected Leghorn; FC = furnished cages; MFC = modified furnished cages; NE = non elevated perches; BE = back perch elevated; FE = front perch elevated.

625a-EU and EV 625A-EU (FC and MFC) was significant. Hens in EV 625A-EU were less affected by hyperkeratotic sole pad alterations. Statistical analysis of the trait sole pad lesions in trial 2 revealed similar results as in trial 1. In layers housed in EV 625a-EU, sole pad lesions were significantly more severe than in hens kept in AP. Furthermore, the results of trial 1 could be approved for the trait hyperkeratosis in the region between toe and claw. Layers housed in AP showed significantly more severe hyperkeratosis in this particular region compared to hens kept in EV 625a-EU and EV 625A-EU. Different perch positions within EV 625a-EU and EV 625A-EU had a significant influence on foot pad status. Layers kept in FC (only NE-perches) showed significantly more severe sole pad lesions than layers housed in MFC-compartments with BE-perches. In FE-compartments of MFC, hyperkeratosis of the region between toe and claw was less severe than in FC (Table 7). Laying hens housed in MSG showed significantly more severe sole pad lesions in FE-compartments than in compartments with ST-perches ($p = 0.037$). Layers' body weight had a significant influence on sole pad lesions and lesions between toe and claw with heavier hens being more affected. Group size did not have a significant influence on foot pad status in the second trial. The additional statistical analysis including the different claw shortening devices in AP, showed a significant influence on the trait toe pad hyperkeratosis. Hyperkeratotic alterations were more prevalent in compartments equipped with abrasive blocks compared to those with perforated metal plates.

Histological foot pad evaluation

Mild extension of stratum corneum (hyperkeratosis) was the most frequently observed finding in sole pads (49.3%) followed by moderate (44.9%) and few cases of severe hyperkeratosis (5.8%). Mild hyperkeratosis was detected in 35.3%, moderate in 54.4% and severe hyperkeratosis in 10.4% of layers' toe pads. Development of secondary papillae was seen in 24.6% of sole pads and 20.6% of toe pads. The observed extension of stratum corneum was often accompanied by proliferation of stratum spinosum (acanthosis). Acanthosis was observed in 73.9% of sole pads and in 69.1% of toe pad samples. Furthermore, an elongation of rete folds was detected in 33.3% of sole pads and in 25% of toe pads. Erosion and ulceration was only observed in sole pads (5.8 and 4.4%). In nearly all samples, an infiltration with inflammatory cells could be observed. Inflammatory infiltration was mostly found as a marked perivascular infiltration of lymphocytes in the dermis. Surfaces of 63.8% of sole pad and 76.5% of toe pad samples were colonised by bacteria. With respect to the different housing systems, severe hyperkeratosis of sole and toe pads was observed in EV 625a-EU (SG and MSG) and EV 625A-EU (FC and MFC). In EV 625A-EU, 4.8% of layers' sole pads and 14.3% of toe pads were affected by severe hyperkeratosis. In EV 625a-EU, 12.5% of sole and 17.4% of toe pads showed severe hyperkeratotic alterations. Erosions were detected in 16.7% and ulcerations in 12.5% of sole pads of layers kept in EV 625a-EU. The incidence of severe lymphocyte infiltration in sole pads was highest in hens housed in EV 625a-EU.

Discussion

Housing system is an important factor influencing the occurrence and type of foot pad alterations (Tauson and Abrahamsson, 1994; Keutgen et al., 1999; Weitzenbürger et al., 2005). In the present study, three different types of housing systems were evaluated with respect to foot pad health. The furnished cage system AP was equipped with perches on an even level in both trials, whereas perches in the small group housing system EV 625a-EU (SG) and the furnished cage system EV 625A-EU (FC) were modified in height and position (MSG, MFC). Housing system had a significant influence on foot pad status in both trials. Including all different perch-variants within the housing systems EV 625a-EU (SG and MSG) and EV 625A-EU (FC and MFC), sole pad alterations were assessed significantly highest in EV 625a-EU. In contrast to the other housing systems evaluated in the present study, the supply pipe of dust bath filling in EV 625a-EU provided a further perching-opportunity. Its relatively rough surface could have led to proliferation of sole pad skin and furthermore to lesions. The supply pipe had a diameter of approximately 45 mm and offered a larger contact area to the hens` feet than

perches. If the large and rough surface was contaminated with excrements, it could have possibly taken a longer time for excrements to be removed (compared to the smooth plastic perches), thus bringing about a possible risk of inflammation of the hens` feet. The occurrence of bumble foot (inflamed and swollen sole pad) is associated with poor perch design and perch hygiene (ELSON and CROXALL, 2006). A relation between the occurrence of hyperkeratotic sole pad alterations and the use of the supply pipe for perching in EV 625a-EU (SG) was also seen by WEITZENBÜRGER et al. (2005). OESTER (1994) mentioned that the mechanical exposure to hens' feet may be related to the time hens are sitting or staying on perches without changing their position. In both trials, hens kept in AP showed significantly higher scores for the trait hyperkeratosis within the region between toe and claw compared to layers kept in the other housing systems tested. A more severe proliferation of the toe skin in AP might have been caused by less frequent use of perches and therefore a longer time hens spent standing on the wire floor. In cage-kept laying hens, toe skin is mostly affected by hyperkeratosis because of the mechanical exposure while grasping the wire floor (KEUTGEN et al., 1999). Perch and cage design is related to foot pad health (TAUSON and ABRAHAMSSON, 1994). SIEGWART (1991) investigated different perch designs and found out that round wooden perches with a flattened surface covered with rubber mats had positive effects on foot pad health in LSL layers. In an investigation by DUNCAN et al. (1992), foot condition in laying hens was found to be most favourable in cages with rectangular perches. In the present study, compartments of EV 625a-EU were equipped with non-elevated rectangular plastic perches (SG) or with non-elevated plastic perches and elevated round metal back perches (MSG BE) in the first trial. In the second trial, compartments with heightened metal front perches (MSG FE) and elevated metal stepped perches (MSG ST) were additionally tested. In contrast to other authors (SIEGWART, 1991; DUNCAN et al., 1992), round perches did not seem to have a negative influence on foot pad health. Sole pad lesions within MSG were assessed significantly lower in ST-compartments with two round perches compared to FE-compartments with round and rectangular perches. The length of time laying hens spent roosting on the supply pipe instead of using perches could have led to a higher incidence of sole pad lesions. In both trials, laying hens in EV 625A-EU were housed in BE- and FE-compartments (MFC) and in those with non-elevated perches (FC). The incidence of more severe sole pad hyperkeratosis (first trial) and sole pad lesions (second trial) in layers housed in FC-compartments could have been caused by preferential use of NE-perches instead of elevated perches in BE- and FE-compartments of MFC. In the first trial, hens kept in BE-compartments of MFC were more severely affected by toe pad hyperkeratosis than layers housed in FE-compartments of MFC. Furthermore, LB hens kept in BE-compartments of MFC also showed more severe toe pad hyperkeratosis than LB layers in FC. These alterations could have possibly caused by long-term standing on the wire floor instead of using perches. It could have been possible that hens in BE-compartments preferred the non-elevated perches instead of the elevated ones. As in FC NE-perching space was insufficient in accommodating a larger group of laying hens at the same time, hens had to switch to other cage areas. The epidermis consists of a multilayered keratinising squamous epithelium. Its thickness is related to the body region and consequently correlated to mechanical exposure as well as to chronic stimuli (MICHEL, 1992). In the histological examination of sole and toe pads, hyperkeratotic alterations were found in all samples tested. In agreement with WEITZENBÜRGER et al. (2006), extension of the epidermis by hyperkeratosis was often associated with proliferation of stratum spinosum (acanthosis). In sole and toe pad samples, a colonisation of bacteria was often observed. The risk of colonisation by microorganisms increased, if skin-surface had been changed by hyperkeratotic alterations, thus facilitating the adhesion of bacteria (WEITZENBÜRGER et al., 2006). In the present study, hens were put into transport boxes for approximately two hours before evaluation of foot pad status and taking skin samples for histological examination. As hens' feet had been in direct contact to their excrements during transport, this could have led to an increased bacterial colonisation of the epidermal surface. In nearly all sole and toe pad samples examined, perivascular infiltrations of lymphocytes were detected. In general, very few numbers of lymphocytes, macrophages and plasma cells occur in unaltered skin. In our investigations, findings on inflammatory cells ranged up to severe infiltrations of foot pad skin. In the majority of cases, these infiltrations were not accompanied by erosions or ulcerations. In an investigation by MAYNE et al. (2006), a dense mass of inflammatory cells was seen in foot pad samples of turkeys with an intact epidermis. WEITZENBÜRGER et al. (2006) also observed a marked perivascular infiltration of lymphocytes in foot pad samples of laying hens without macroscopic alterations of the skin. In the present study, all samples on sole and toe pads were affected by hyperkeratosis, so that the high incidence of inflammatory cells could have been caused by the exposure of hens` feet to perches and floor. In correspondence to WEITZENBÜRGER et al. (2006), we conclude that the macroscopically and histologically observed hyperkeratotic alterations in foot pads were caused by a continuous mechanical stimulus to the skin while grasping the wire floor or using perches. The incorporation of perches at different heights was found to have a positive impact on foot pad status. Sole pad hyperkeratosis in FE-compartments (first trial) and sole pad lesions in BE-compartments of MFC (second trial) were less severe compared to alterations found in layers housed in FC. No significant differences in foot pad status could be detected between the different perch-variants in EV 625a-EU (SG and MSG), except for LSL layers which had been more affected by sole pad lesions in FE- than in ST-compartments of MSG (second trial). The trait hyperkeratosis between toe and claw seemed to be influenced by layer line. In both trials, LSL hens kept in FC were significantly more severely affected compared to LSL layers in FE-compartments of MFC, whereas LB layers (first trial) in BE-compartments of MFC were more affected by hyperkeratotic alterations in this particular region.

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Summary

Foot pad health in Lohmann Selected Leghorn (LSL) and Lohmann Brown (LB) laying hens kept in a modified small group housing system (Eurovent (EV) 625a-EU (MSG), four perches) equipped with perches at different levels, a modified furnished cage system (EV 625A-EU (MFC), two perches) with the back or the front perch being elevated, a small group housing system (EV 625a-EU (SG), four

non-elevated perches), and furnished cages with (two) non-elevated perches (EV 625A-EU (FC), Aviplus (AP)), was evaluated in two trials. The occurrence of hyperkeratosis and epithelial lesions was macroscopically assessed in 576 laying hens (432 LSL, 144 LB) and classified due to the severity of alterations. In the first trial, 69 samples of sole pads and 68 toe pad samples were examined histologically. Mild hyperkeratosis was the most frequent macroscopic finding and epithelial lesions were observed in hens of all housing systems evaluated. Modified perch positions had a positive influence on some traits of foot pad health. Histological examinations revealed hyperkeratosis in sole and toe pad samples in all cases. Mild hyperkeratosis was the predominant finding in sole pads, whereas in toe pads, moderate hyperkeratosis was prevailing. Severe cases of hyperkeratosis could be observed in FC, MFC, SG and MSG. Erosions and ulcerations were found in sole pad samples of hens kept in SG and MSG. Perivascular infiltration of lymphocytes was observed in nearly all sole and toe pad samples examined.

Key words

Laying hen, small group housing system, foot pad health, perch position

Zusammenfassung

Fußballenstatus von Lohmann Selected Leghorn und Lohmann Brown Legehennen in unterschiedlichen Haltungssystemen mit modifizierter Sitzstangenposition

In zwei Legedurchgängen wurde der Fußballenstatus von Lohmann Selected Leghorn (LSL) und Lohmann Brown (LB) Legehennen erfasst, die in einem modifizierten Kleingruppenhaltungssystem (Eurovent (EV) 625a-EU (MSG)) mit (vier) Sitzstangen auf unterschiedlichen Ebenen, einem modifizierten ausgestalteten Käfigen (EV 625A-EU (MFC) mit zwei Sitzstangen), in denen die hintere oder vordere Sitzstange erhöht war, einem Kleingruppenhaltungssystem (EV 625a-EU (SG) mit vier Sitzstangen auf einer Ebene) sowie ausgestalteten Käfigen (EV 625A-EU (FC), Aviplus (AP) mit zwei Sitzstangen auf einer Ebene) gehalten wurden. Hyperkeratosen und Epithelläsionen wurden bei insgesamt 576 Hennen (432 LSL, 144 LB) makroskopisch erfasst und hinsichtlich ihres Schweregrades klassifiziert. Im ersten Legedurchgang wurden 69 Sohlen- und 68 Zehenballen histologisch untersucht. Makroskopisch wurden hauptsächlich geringgradige Hyperkeratosen festgestellt. Epithelläsionen traten in allen Haltungssystemen auf. Ein positiver Einfluss der modifizierten Sitzstangenanordnung konnte auf einige Merkmale des Fußballenstatus ermittelt werden. Alle histologischen Präparate waren von hyperkeratotischen Veränderungen betroffen. Während Sohlenballen vorwiegend geringgradige Hyperkeratosen aufwiesen, zeigten Zehenballen vornehmlich mittelgradige Veränderungen. Hochgradige Hyperkeratosen wurden bei Legehennen aus den Haltungssystemen FC, MFC, SG und MSG beobachtet. Erosionen und Ulzerationen traten in Sohlenballenproben von Hennen aus den Systemen SG und MSG auf. Perivaskuläre Infiltrationen von Lymphozyten konnten in fast allen Fußballenpräparaten festgestellt werden.

Stichworte

Legehenne, Kleingruppenhaltung, Fußballenstatus, Sitzstangenposition

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