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A walk through the broiler breeder life: how do footpad dermatitis and gait scores develop from rearing to slaughter?

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ABSTRACT

The two most common animal-based indicators used to evaluate leg health in broiler chickens are footpad dermatitis (FPD) and gait scoring, but these indicators are less explored in broiler breeders. This study is the first to investigate FPD and gait scoring in broiler breeders during their lifespan from rearing to end of life. In total, eight flocks were monitored (four Ross and four Hubbard) at five different timepoints, in rearing (5 and 15 weeks of age), during the production period (25 and 45 weeks of age) and at the end of the production period (approximately 60 weeks of age). At each visit, 50 hens and 25 roosters were gait scored (six-point scale) and footpads from another 50 hens and 25 roosters were evaluated (five-point scale) (total $n = 3000$ breeders, 2000 hens and 1000 roosters). Litter quality and air quality were measured at each visit. The results showed that the overall prevalence of FPD in rearing was low and that it increased towards the end of the production, with a mean FPD score of 2 out of a maximum 4 in the hens, indicating moderate lesions and 1.5 in the roosters. In all houses, the litter was dry and loose. FPD was not related to the litter quality, but to air quality, especially the ammonia concentration ($P < 0.001$). Overall, the gait score were good, and increased with age in both hens ($P < 0.001$) and roosters of both hybrids ($P < 0.001$).

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Broiler breeders; breeders; parent stock; footpad lesions; footpad dermatitis; gait score

Introduction

Footpad dermatitis (FPD) and gait scores are the two most common animal-based indicators used to evaluate leg health in broiler chickens (Bassler *et al.*, 2013). FPD, also called pododermatitis, hyperkeratosis or footpad lesions (De Jong *et al.*, 2012), is a type of contact dermatitis that causes inflammation and necrotic lesions on the plantar surface of the footpads, often observed in broiler chickens and turkeys (Ekstrand *et al.*, 1998; Shepherd & Fairchild, 2010; Opengart *et al.*, 2018). The lesions start with discolouration of the skin, eventually followed by hyperkeratosis, severe erosions and necrosis (Kyvsgaard *et al.*, 2013). FPD may range from superficial lesions to severe, deep necrotic ulcers on the footpads and toes (Shepherd & Fairchild, 2010). The associated pain may negatively affect the gait and reduce the bird's mobility (Haslam *et al.*, 2007; Sirri *et al.*, 2007).

FPD in broiler chickens has been investigated since the 1980s (Greene *et al.*, 1985). The prevalence varies between different studies, but the overall prevalence of FPD in fast-growing broiler flocks has been found to be high at slaughter age (Haslam *et al.*, 2007; Bassler *et al.*, 2013). Environmental factors, like moisture and particle size of the litter, stocking density, and ammonia irritation from the bedding, are thought to be important causative factors (Cengiz *et al.*, 2011;

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Kyvsgaard *et al.*, 2013; De Jong *et al.*, 2014) and, as such, the footpad health reflects the environment in the barn and the farmer's management. Due to welfare concerns, scoring of FPD is used as an animal-based indicator in the broiler industry in the EU where the feet are monitored *postmortem* at the abattoir for all broiler chicken flocks slaughtered commercially. The scoring system uses a scale based on lesion severity (Ekstrand *et al.*, 1998). High flock scores will elicit sanctions on animal density in future production cycles in Norway, Denmark and Sweden. Scoring of footpad lesions is mandatory for all broiler chicken flocks slaughtered in the EU, but not for the broiler breeders and, therefore, available FPD data from commercial breeder production are scarce. In addition, compared to the literature on FPD in broiler chickens, available studies on FPD in broiler breeders are few, in terms of both prevalence and risk factors, but studies have shown that footpad health declines with the age of the breeders (Kaukonen *et al.*, 2016; Thøfner *et al.*, 2019). Since the breeders live approximately 55–60 weeks longer than the broiler chickens, it is of utmost importance to determine at which age FPD develops and how the footpad health develops and progresses through the life of the broiler breeders, from rearing to slaughter.

Gait scoring (GS) is a widespread method used to evaluate locomotion and lameness in broiler chickens. The method defines gait on a six-point scale (Kestin *et al.*, 1992). GS has been used in broiler chickens for several decades, since it is an easy tool for leg health monitoring on farm. GS provides information about the way the bird moves, but cannot differentiate between the causes of gait abnormalities, which may be of both infectious and non-infectious aetiology (Opengart *et al.*, 2018). Fast growth and high body weight are thought to be primary risk factors for poor locomotion (Knowles *et al.*, 2008). Several studies indicate that modern fast-growing broiler chickens have a high prevalence of impaired locomotion, especially towards the end of the production period (Knowles *et al.*, 2008; Kittelsen *et al.*, 2017; Granquist *et al.*, 2019). Despite the importance and widespread use of GS in broiler chickens, there are few studies available on GS in broiler breeders. This lack of information is striking, since the breeders have the same genetic growth potential, live longer but are raised to different weight and under different housing conditions and with restricted feeding during parts of their life. To the authors' knowledge, such a life span analysis has never been conducted in broiler breeders, neither under experimental nor under commercial conditions, and will give important information about broiler breeder health and welfare.

The main aim of this study was to deliver descriptive information about the prevalence and severity of FPD and GS in broiler breeders at different time points through their life span, from early rearing to slaughter age. Additional objectives were to assess risk factors for FPD in the broiler breeder and to investigate the potential relationship between FPD and GS.

Materials and methods

Animals and housing

The data were collected from spring 2022 to autumn 2023 in Norwegian broiler breeder flocks. The study population consisted of a total of eight rearing flocks (Ross 308, $n = 4$ and Hubbard JA757, $n = 4$) and the eight production flocks (Ross 308, $n = 4$ and Hubbard JA757, $n = 4$) they were transferred to. The flocks were visited five times; at 5, 15, 25 and 45 weeks of age (WOA), and finally close to the time of slaughter (range: 55–62 WOA). All flocks were kept in enclosed, heated and environmentally controlled houses. Management practices followed the recommendations from the breeding companies and Norwegian regulations. The main difference between the feed regimes for the two hybrids was that feed was more restricted for the Ross 308 hens during rearing.

The non-beak-trimmed day-old chicks arrived at the rearing farm straight from the hatchery. In the rearing barns, the pullets and cockerels were housed in different compartments in the same barn, separated by netting walls or in separate rooms. The floors of all barns and compartments were covered with fresh wood shavings as litter material. The number of pullets placed ranged from 6997 to 9682, equalling an animal density of 8–10 birds per m^2 at 5 WOA. The number of cockerels placed ranged from 660 to 2186, equalling an animal density of 4–12 birds per m^2 at 5 WOA. Hours with light per day ranged from 8-13 h, depending on the age and according to the breeder manual. Light intensity during light hours was 4–8 at week 5, and 5–28 at 15 WOA, measured at animal height with a luxometer (Extech LED meter LT40, FLIR Commercial Systems Inc., Nashua, NH, USA). The light programme differed between the breeds; both followed their breeding manuals for their age. All rearing flocks were fed commercial, pelleted feed using a spin-feeder once per day, ranging from 40–50 g/bird at 5 WOA for hens and 60–65 g/bird for the roosters. At 15 WOA, the hens were fed 61–86 g/day and the roosters 85–95 g/day. The roosters were transferred to the production barns at 17 WOA, and the hens at 18 WOA. The average live weight for Hubbard hens at 18 WOA was 1680 g, while the corresponding weight for Ross 308 hens was 1950 g, as expected because of the genetic differences between the hybrids.

All breeder flocks consisted of approximately 7500 placed hens (range: 6980–7566) and 650 placed roosters (range: 600–803), kept in the same house. The barn size varied from 1230 to 1600 m^2. Mean animal density was 5.85 birds/m^2 (range 5.0–6.6, average for the Ross flocks: 5.25, average for the Hubbard flocks: 6.45) at week 25. All production barns were of the same design; fully insulated, with an identical mechanical ventilation system, no windows, and concrete floor with fresh wood shavings, elevated slats (height: 60 cm) with nest boxes, and round, metal perches on the slats. The elevated slats were approximately 2.4 m in width (range: 1.2–5.0 m) and covered a mean area of 500.2 m^2 (range: 144.0–948.0 m^2). This constituted a mean 38.3% of the area in the barn (range: 11.6–74.4%). The light regime included 8 h of darkness per day, and lux during light periods varied from 5–30 in different barns at 25 WOA, measured at animal height with a luxometer. All flocks were fed commercial pelleted feed. Rooster feed lines were situated in the litter area and hen feed lines on the slatted area. Food was provided 2–4 times per day, in an amount according to the management guide of the breeding companies, ranging from 115–135 g per day for the hens and from 93–150 g for the roosters. The amount varied with age and with hybrid. Water was provided from 8:30 to 12:30 h and from 15:30 to 16:00 h via drinking nipples. The birds were either culled on-farm or slaughtered at a commercial poultry abattoir at the age of 55–62 weeks.

Sampling methods

Footpad investigation

FPD was investigated at five different times for each flock (5, 10, 25, 45 WOA and prior to slaughter/culling (range: 55–62 WOA)). During each visit, a random selection of 50 hens and 25 roosters per flock were examined. The birds were selected systematically from both the slatted area and from the litter throughout the entire barn at predefined points. The observer scored the bird to the left from the first bird, at the designated points. Assessment of the footpads was based on the presence of visually macroscopic lesions on live birds and scored on a five-point scale (Figure 1) according to the Welfare Quality Assessment Protocol for Poultry (Welfare Quality, 2009). The surface area of both footpads was examined after brushing off litter and faecal material with a semi-hard brush. In cases of discrepancy between the footpads, the highest score was recorded for that bird. A score 0 represents no evidence of FPD, scores 1 and 2 represent small to moderate evidence of FPD, while scores 3 and 4 represent evidence of severe FPD, according to the Welfare Quality Assessment Protocol for Poultry (Welfare Quality, 2009; see Figure 1).

Table 1. Explanation of the gait score criteria[a].

Gait score	Criteria
0	No detectable abnormality, fluid locomotion, furled foot when raised
1	Slightly abnormal gait, difficult to define
2	Definite and identifiable defect, but does not hinder the broiler in movement
3	Obvious lameness that affects the broiler's ability to manoeuvre, accelerate and gain speed
4	Severe gait lameness: the broiler is reluctant to walk and will walk only a couple of steps, if driven, before sitting down
5	Complete lameness on one or both legs, either unable to walk or no/minimal weight-bearing on the legs

[a]In accordance with Kestin *et al.* (1992).

Gait scoring

Walking ability was investigated by the same observer at four different times for each flock (5, 10, 25 and 45 WOA). During each visit, a random selection of 50 hens and 25 roosters per flock was investigated. The birds were selected at designated points in the barn, from both the slatted area and from the litter, when the trained investigator walked slowly throughout the barn, in order to avoid resampling. The observer scored the bird to the left from the first bird encountered, at the designated points. Walking ability was evaluated using the six-point gait scoring scale as described by Kestin *et al.* (1992), see Table 1. Scoring of individual broilers took between 5 and 30 s. Birds that did not walk away within approximately 30 s were encouraged to walk by slowly walking behind them.

Litter

In all barns, both rearing and production, the bedding consisted of fresh wood shavings, approximately 5–15 cm deep in different areas of the barn. The litter

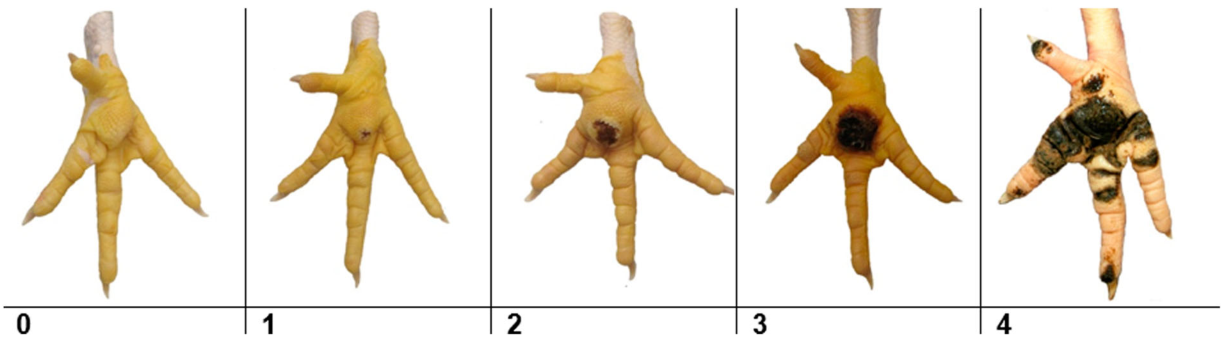

Figure 1. Scoring of FPD according to the Welfare Quality Assessment Protocol (Welfare Quality, 2009). © A Butterworth, University of Bristol.

Table 2. Scoring of litter quality according to the Welfare Quality Assessment Protocol.

Litter quality	Classification
0	Completely dry and flaky, i.e. moves easily with the foot
1	Dry but not easy to move with the foot
2	Leaves imprint of foot and will form a ball if compacted, but the ball does not hold together well
3	Sticks to boots and sticks readily in a ball if compacted
4	Sticks to boots once the cap or compacted crust is broken

was assessed at six different places. The litter quality was recorded according to the score described in the Welfare Quality Assessment Protocol for Poultry (Welfare Quality, 2009) ranging from 0 for dry and flaky litter to 4 for solid litter covered with a crust (Table 2).

At all five visits, carbon dioxide was measured with a CO_2 Meter (Extech) and ammonia was measured by Dräger Pac 8000 (©Drägerwerk AG & Co., Lübeck, Germany).

Statistical analysis

Statistical analyses were performed using the software SAS 9.4. The statistical unit was flock by hybrid by age. The eight flocks followed in the study were each visited at five different ages, giving a total of 40 flock visits (20 flock visits for each hybrid). Unfortunately, two of the visits could not be performed due to COVID/illness. Therefore, the final total of flock visits was 38. The data from the individual assessment of FPD and GS were averaged for each sex per flock per age, calculated from the 50 hens and 25 roosters assessed in each flock at each age. The effects of hybrid and age on the FPD and GS were investigated for each sex using the mixed procedure model, which included hybrid, age and their interaction as fixed factors and flock ID as a random factor. The data fit the model assumptions, e.g. normal distribution of the residuals. *Post-hoc* analyses were performed with the Tukey test (Tukey's honestly significant difference (HSD) test).

The relationships between FPD and GS and the investigated risk factors measured on the farm were assessed using Pearson correlations. The risk factors included in the analyses were: light intensity (Lux), ammonia concentration (ppm), carbon dioxide concentration (ppm), hen mortality (%), density in the production farm (birds per m^2), slatted area (% of total floor area) and width of the slats (m). Since the litter was always dry and loose, it did not have enough variability to be included in the data analysis. Due to the low numbers of flocks per hybrid per age, age was not included as a factor in the analyses of correlations. Nevertheless, hybrid was taken into account by running separate correlations for each hybrid.

Results

The FPD distributions over age, hybrid and gender are presented in Figure 2(A–D). Among the female birds, there was an interaction between hybrid and age on their scores for FPD ($F_{4,22} = 2.97$; $P = 0.04$). For the Ross 308 birds, these scores increased steadily with age, with significant differences observed already

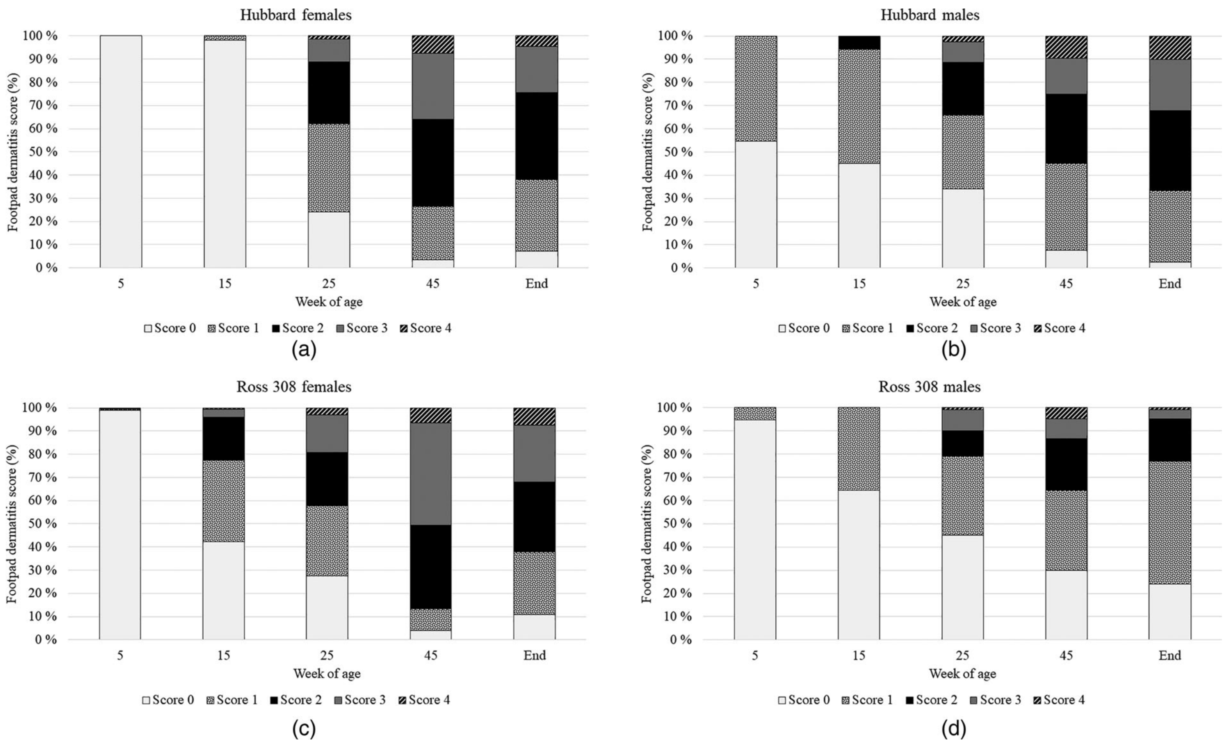

Figure 2. (A) FPD scores in Hubbard hens at different timepoints. (B) FPD scores in Hubbard roosters at different timepoints. (C) FPD scores in Ross 308 hens at different timepoints. (D) FPD scores in Ross 308 roosters at different timepoints.

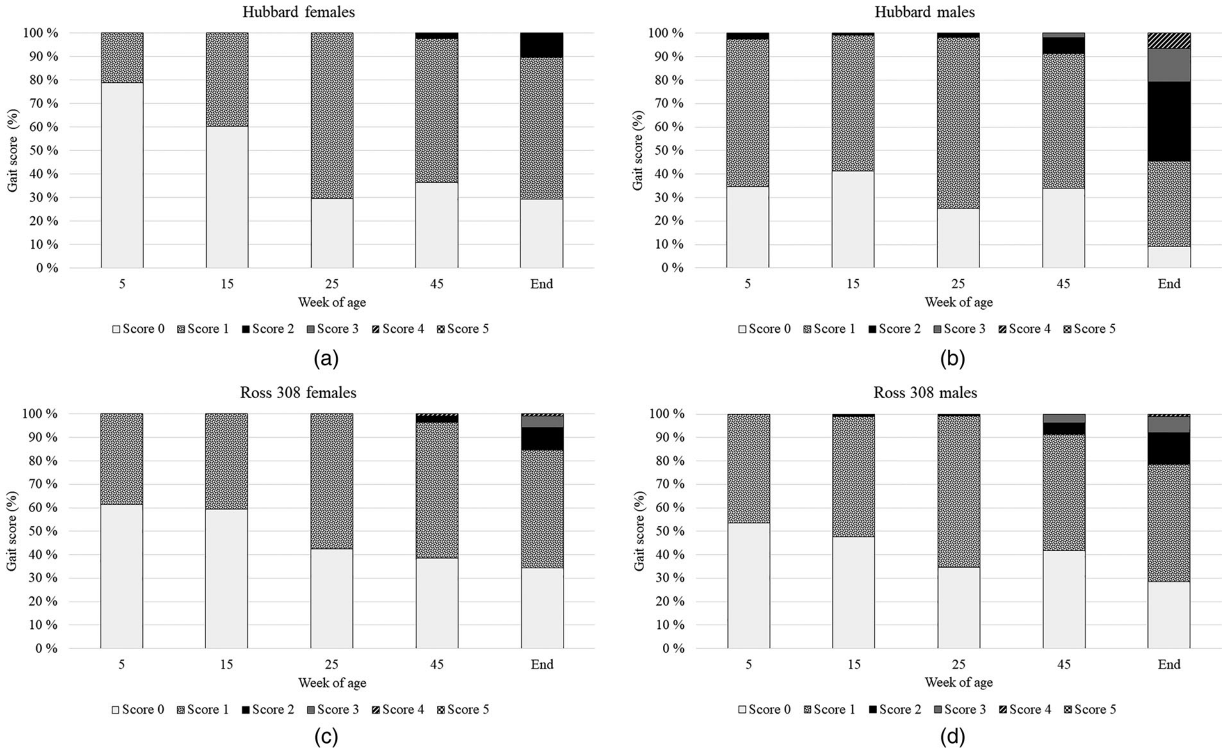

Figure 3. (A) Gait scores in Hubbard hens at different time points. (B) Gait scores in Hubbard roosters at different timepoints. (C) Gait scores in Ross hens at different timepoints. (D) Gait scores in Ross roosters at different timepoints.

between weeks 5 and 15 of age ($P < 0.05$). In comparison, the scores of the Hubbard birds started increasing from 0 only after the second assessment, sometimes between 15 and 25 WOA, and continued to increase thereafter ($P < 0.05$). Furthermore, there was no significant difference between the hybrids at any of the ages ($P > 0.05$ after correction for multiple comparisons). For the male birds, there was no interaction between hybrid and age on FPD ($F_{4,23} = 0.86$; $P = 0.50$). However, there was an effect of hybrid ($F_{1,6} = 15.48$; $P < 0.01$), where Hubbard birds had higher FPD scores than Ross 308 birds (LS mean ± SE: Hubbard = 1.26 ± 0.11; Ross 308 = 0.68 ± 0.10). As expected, an effect of age was also found, with the score for FPD increasing with age from week 15 of age ($F_{4,23} = 14.71$; $P < 0.0001$).

The GS distributions over age, hybrid and gender are presented in Figure 3(A–D). Regarding the GS, there was no effect of hybrid on the score of the female birds (LS mean ± SE: Hubbard = 0.55 ± 0.04; Ross = 0.58 ± 0.04; $F_{1,6} = 0.29$; $P = 0.61$). The GS did, nevertheless, increase with age as expected ($F_{4,22} = 15.45$; $P < 0.0001$). For the males, however, there was an observed effect of hybrid, where the Hubbard birds had a higher overall GS (LS means ± SE: 0.91 ± 0.06) compared to the Ross birds (LS means ± SE: 0.67 ± 0.06; $F_{1,4} = 7.96$; $P = 0.04$). Across both hybrids, male GS remained relatively stable until 45 WOA and increased thereafter ($F_{4,21} = 10.73$; $P < 0.0001$).

Including all ages, there was a strong positive correlation between the scores of FPD between male and female birds in each flock (Pearson correlation coefficient: 0.71; $n = 38$; $P = < 0.0001$) and between FPD and GS of female birds (Pearson correlation coefficient: 0.64; $n = 38$; $P = < 0.0001$). For the male birds, also within flocks, there was a medium positive correlation between FPD and GS (Pearson correlation coefficient: 0.59; $n = 38$; $P = < 0.0001$). In addition, there was a medium positive correlation between female GS and male GS (Pearson correlation coefficient: 0.56; $n = 38$; $P = 0.0002$).

Descriptive statistics for the risk factors for FPD assessed on farm in Ross 308 and Hubbard flocks

Table 3. Descriptive statistics for the Ross 308 flocks.

		Week of age				
		5	15	25	45	End
Light intensity (Lux)	Mean	5.0	5.0	8.5	13.5	17.5
	Std Dev	0.0	0.0	4.4	5.0	5.3
	Min	5.0	5.0	2.0	8.0	10.0
	Max	5.0	5.0	12.0	20.0	22.0
NH_3 (ppm)	Mean	3.3	7.3	26.0	39.5	28.8
	Std Dev	1.5	5.5	7.3	11.2	7.1
	Min	2.0	2.0	16.0	25.0	20.0
	Max	5.0	12.0	32.0	52.0	37.0
CO_2 (ppm)	Mean	1259.8	1331.8	1923.3	2287.5	1807.5
	Std Dev	65.1	312.4	363.3	356.8	132.5
	Min	1220.0	1009.0	1579.0	1800.0	1688.0
	Max	1356.0	1620.0	2251.0	2600.0	1984.0
Hen mortality (%)	Mean	2.9	3.3	1.6	4.4	6.4
	Std Dev	0.6	1.4	1.2	3.3	3.6
	Min	2.0	1.5	0.6	1.2	3.0
	Max	3.5	4.8	2.9	7.5	10.6
Density (birds/m^2)	Mean	na	na	5.6	5.2	5.1
	Std Dev	na	na	0.3	0.1	0.0
	Min	na	na	5.3	5.2	5.1
	Max	na	na	5.8	5.3	5.2

Notes: Mean, Std Dev, Min and Max values for the risk factors for FPD assessed on Ross 308 flocks across week of age. na: not applicable.

Table 4. Descriptive statistics for the Hubbard flocks.

		Week of age				
		5	15	25	45	End
Light intensity (Lux)	Mean	6.5	8.0	23.3	25.5	25.0
	Std Dev	2.1	2.0	7.0	5.3	8.7
	Min	5.0	6.0	15.0	20.0	15.0
	Max	8.0	10.0	30.0	30.0	30.0
NH_3 (ppm)	Mean	3.7	7.8	28.5	36.0	29.0
	Std Dev	0.6	2.9	5.0	31.2	0.0
	Min	3.0	4.0	22.0	11.0	29.0
	Max	4.0	11.0	34.0	79.0	29.0
CO_2 (ppm)	Mean	1957.3	1734.3	1639.3	2175.3	1995.0
	Std Dev	498.5	358.5	534.6	906.3	148.5
	Min	1382.0	1434.0	1158.0	1458.0	1890.0
	Max	2260.0	2230.0	2241.0	3500.0	2100.0
Hen mortality (%)	Mean	2.3	4.9	0.4	5.4	8.5
	Std Dev	2.4	2.8	0.2	5.4	4.6
	Min	0.5	2.3	0.2	1.9	5.6
	Max	5.1	7.8	0.5	13.4	13.8
Density (birds/m^2)	Mean	na	na	6.5	6.4	6.1
	Std Dev	na	na	0.2	0.2	0.4
	Min	na	na	6.2	6.2	5.6
	Max	na	na	6.7	6.7	6.5

Notes: Mean, Std Dev, Min and Max values for the risk factors for FPD assessed on Hubbard flocks across week of age. na: not applicable.

are presented in Tables 3 and 4, respectively. Likewise, the correlations between the scores for FPD and GS and the on-farm risk factors are presented in Tables 5 and 6 for Ross 308 and Hubbard birds, respectively.

Light intensity measured in lux was medium to strongly positively correlated to the scores of both hybrids and sexes. The only exceptions were the lack of correlation between light intensity and FPD of Ross hens and GS of Hubbard roosters. Litter quality was loose and dry in the production barns, all scores 0, and there was no correlation between litter quality and FPD. Likewise, in the rearing facilities, the litter was dry and loose (score 0) in the pullet compartments at both 5 and 15 WOA. However, in the cockerel departments, the litter was moist at both 5 and 15 WOA, with a medium score of 1.5. Air quality assessed in the concentrations of ammonia and carbon dioxide had medium to very strong positive correlations with FPD scores of Ross 308 birds of both genders. The scores of Hubbard birds, on the other hand, seemed less affected by CO_2, but still showed medium to strong positive correlations with ammonia. Hen mortality did not correlate with the scores for FPD or gait of the hens of either hybrid. Stocking density, the number of birds per m^2 in the production farm, showed medium to strong negative correlations with the gait of hens of both hybrids and the FPD scores of Ross hens. Finally, there was no observed correlation between the percentage area of the slats or the width of the slats on the leg health of male or female birds of either hybrid.

Discussion

The main aim of this study was to deliver descriptive information about the prevalence and severity of FPD and GS in broiler breeders, both hens and roosters, at different timepoints through their lifespan, from early rearing to slaughter. Based on previous broiler breeder research, we hypothesized that the incidence and severity of FPD would increase with age (Kaukonen *et al.*, 2016; Thøfner *et al.*, 2019; van den Oever *et al.*, 2020). Our results showed that the prevalence of FPD was low in rearing (age 5 and 15 weeks) for hens of both hybrids, but slightly higher for the Ross hens compared to the Hubbard hens.

Table 5. Pearson correlation coefficient results for the Ross 308 flocks.

		Females						Males					
		FPD			Gait score			FPD			Gait Score		
Risk factor	Unit	PEARSON	*P*	*n*	PEARSON	*P*	*n*	PEARSON	*P*	*n*	PEARSON	*P*	*n*
Light intensity	Lux	0.49	0.054	16	0.57	**0.02**	16	0.76	**0.0007**	16	0.67	**0.004**	16
NH_3	ppm	0.80	**<.0001**	20	0.52	**0.02**	20	0.91	**<.0001**	20	0.58	**0.008**	20
CO_2	ppm	0.74	**0.0002**	20	0.46	**0.04**	20	0.82	**<.0001**	20	0.52	**0.02**	20
Hen mortality	%	0.35	0.14	19	0.22	0.37	19	0.55	**0.016**	19	0.29	0.23	19
Density	birds/m^2	−0.59	**0.04**	12	−0.60	**0.04**	12	−0.15	0.63	12	−0.51	0.09	12
Slats area	% area	0.46	0.13	12	−0.34	0.28	12	0.18	0.56	12	−0.27	0.4	12
Slats width	m	0.50	0.09	12	−0.24	0.44	12	0.10	0.74	12	−0.17	0.6	12

Notes: Significant *P*-values (< 0.05) are marked in **bold.** *P*-values and number of observations between the risk factors assessed on farm and FPD and gait score for hens and roosters Ross 308 broiler breeders.

Table 6. Person correlation coefficient results for the Hubbard flocks.

		Females						Males					
		FPD			Gait score			FPD			Gait score		
Risk factor	Unit	PEARSON	*P*	*n*	PEARSON	*P*	*n*	PEARSON	*P*	*n*	PEARSON	*P*	*n*
Light intensity	Lux	0.71	**0.002**	16	0.60	**0.01**	16	0.67	**0.004**	16	0.35	0.18	16
NH_3	ppm	0.65	**0.005**	17	0.59	**0.01**	17	0.59	**0.01**	17	0.13	0.61	17
CO_2	ppm	0.23	0.37	17	0.13	0.61	17	0.13	0.62	17	−0.04	0.89	17
Hen mortality	%	0.17	0.51	17	0.09	0.73	17	0.27	0.3	17	0.55	**0.02**	17
Density	birds/m^2	−0.04	0.92	11	−0.73	**0.01**	11	−0.28	0.4	11	−0.27	0.42	11
Slats area	% area	−0.41	0.21	11	−0.13	0.69	11	−0.04	0.9	11	−0.32	0.34	11
Slats width	m	−0.41	0.21	11	−0.17	0.62	11	−0.05	0.88	11	−0.31	0.36	11

Notes: Significant *P*-values (< 0.05) are marked in **bold**. *P*-values and number of observations between the risk factors assessed on farm and FPD and gait score for female and male Hubbard broiler breeders.

Only mild lesions were observed in rearing. The scores in both hybrids increased steadily from 25 WOA, which is somewhat earlier than the reported findings (Kaukonen *et al.*, 2016; Thøfner *et al.*, 2019). From week 25 to the end of the production, the FPD results were similar for hens of both hybrids. At the last visit (55–62 WOA), the mean FPD score for the hens was 2, which is slightly lower than what was reported by Kaukonen *et al.* (2016). The prevalence of FPD in roosters in rearing was slightly higher compared to the observed lesions in hens at the same age. Thereafter, the FPD in the roosters increased steadily from week 15 of age. Hubbard roosters had slightly higher FPD scores than Ross 308 roosters. During the last visit (55–62 WOA), the Ross roosters had better footpad scores than the hens at similar ages. To the authors' knowledge, no published papers have investigated the development of FPD throughout the life of the roosters, thus no comparison with previous results can be made. Overall, the prevalence of FPD was surprisingly similar and generally low in all eight flocks, with few variations between birds of the same age in different flocks. Kaukonen *et al.* (2016) found that 0–5.5% of birds had severe FPD at 19, 24 and 36 WOA, after which it significantly increased to 25% at the age of 48 weeks and increased further toward 64% at 60 WOA. In comparison, at weeks 55–62 in our study, 29.1% of the breeder hens and 17.6% of the roosters had severe FPD (i.e. a score 3 or 4). These are lower numbers compared to Kaukonen's study, but still high enough to indicate that FPD is an important health and welfare problem at the end of lay for the broiler breeders, especially since severe lesions are associated with inflammation, infection and pain (Martland, 1984; Gentle, 2011; Sinclair *et al.*, 2015; Weber Wyneken *et al.*, 2015; Thøfner *et al.*, 2019).

In addition to age, bodyweight is a known risk factor for FPD in broiler chickens (Shepherd & Fairchild, 2010), where light broilers are found to have significantly lower FPD and GS than heavier broilers (Opengart *et al.*, 2018). Wolanski *et al.* (2004) assessed the foot condition of 62-week-old broiler breeder roosters and found high bodyweight to have a negative effect on the footpad condition. This is in contrast to our results where no difference between hens of the two hybrids was observed, even though the Hubbard hens are lighter and smaller compared to the Ross 308 breeder hens (Hubbard, 2015; Ross, 2018). This finding is supported by results from other studies, finding footpad scores to be evenly distributed among different bodyweight classes in 62-week-old breeder hens (Renema *et al.*, 2007). Furthermore, there was a hybrid difference in the roosters, even though roosters of the two hybrids are quite similar in size and weight (Hubbard, 2015; Ross, 2018). Due to feed restriction, the breeders grow slower than broiler chickens, perhaps making bodyweight less important in the aetiology of FPD. Unfortunately, we do not have individual weights for the birds assessed for FPD and GS. This should be investigated in future studies.

In the present study, at 55–62 WOA, 29.1% of the hens and 17.6% of the roosters had severe FPD (i.e. a score 3 or 4). These differences between hens and roosters are in line with results from Kapell *et al.* (2012), who found that hens showed higher prevalence of FPD than roosters. Nagaraj *et al.* (2007) have suggested that higher prevalence of FPD in hens is related to a lower content of collagen and protein in the skin of the hens compared to roosters, which may predispose them to skin injuries (Nagaraj *et al.*, 2007). However, this is in contrast to other studies, where higher prevalence of FPD has been observed in roosters (Greene *et al.*, 1985). This shows that the effect of gender on FPD in broiler breeders is still unclear and should be investigated further.

High moisture content in the bedding material may lead to the attachment of litter, and ammonia irritation to the feet (Kyvsgaard *et al.*, 2013). Therefore, litter quality, specifically litter moisture and ammonia content, is listed as the major causative environmental factor for FPD (Martland, 1984; Mayne, 2005; van den Oever *et al.*, 2020). The relationship between FPD and litter quality has been well established in studies from both broiler chickens and broiler breeders (Kaukonen *et al.*, 2016; van den Oever *et al.*, 2020). Overall, the litter quality in our study was good, with dry and loose litter scoring 0. However, during rearing the litter in all the cockerel compartments was moister (average score 1.5) than in the pullet compartments. This may explain why the FPD score in the cockerel flocks was higher than in the pullets. However, during the production phase, the litter was always dry and loose in all areas investigated, at all visits. This indicates that there are other factors besides litter quality that may affect footpad health in the broiler breeder barns. It is obvious that the litter quality is important for birds that spend most of their lives in direct contact with litter material, such as broiler chickens. However, in the breeder production barns that are common in Europe, the nest boxes and the feeder and water lines for the hens are placed on elevated slats. Providing slats has been suggested to benefit foot cleanliness and health (Brake, 1998), but it could also be speculated that these barn adaptations make the hens spend less time in the litter area, thus reducing contact with the litter. Consequently, the hens will defecate more on the slats, and faeces on the slats will not be absorbed by the litter. Hence, the faeces will remain on the slats until they dry out or until a bird steps on them, soiling the footpad. If the bird continues to stay on the slatted area, the faeces will stay attached to the footpad and dry there, making the footpad embedded in solid faecal material with high ammonia content. This will in turn lead to FPD. Kaukonen *et al.*

(2016) found a larger slatted area was related to poorer footpad conditions. In our study, we found no correlation between the percentage area of the slats or the width of the slats on the FPD of male or female birds of either hybrid, which is in accordance with an experimental study where no effects of slats on FPD were observed (van den Oever *et al.*, 2021). Due to the adjusted water and feed line and the nest boxes, the slatted area is more attractive for the hens than the roosters. In addition, mating activity takes place in the litter area. Excessive and aggressive mating can be a problem in the broiler breeder production, making hens stay away from the litter. The feed and water line for the rooters are located in the litter area, making this more attractive for them and they spend more time there than the hens do. It could therefore be speculated that this can be the cause for fewer roosters with lesion scores 3 or 4 at the end of the production period, compared to the results in the hens. This warrants further studies.

The ammonia level in several of the barns was very high; so high that it may be aversive to the birds. These concentrations were measured during the winter with very low outside temperatures, resulting in reduced ventilation to maintain temperature inside the barn. The concentration of ammonia and carbon dioxide measured in the air had medium to very strong positive correlations with FPD scores of Ross 308 birds of both genders. The scores of Hubbard birds, on the other hand, seemed less affected by carbon dioxide, but still showed medium to strong positive correlations with ammonia. This is in line with previous published papers, listing ammonia as one the major causative environmental factors for FPD (Martland, 1984; Dawkins *et al.*, 2004; Mayne, 2005; van den Oever *et al.*, 2020). Further studies should focus on keeping good air quality and low ammonia levels in the winter season.

Lameness and impaired gait are major welfare issues in broiler chickens (Bessei, 2006) with estimated prevalences between 14% and 30% (Knowles *et al.*, 2008; Kittelsen *et al.*, 2017; Granquist *et al.*, 2019). Birds with scores ≥ 3 are considered to have an impaired gait since this affects manoeuvrability, speed and acceleration and is likely associated with pain (Kestin *et al.*, 1992; McGeown *et al.*, 1999). Overall, the GS were low in our study, in both hens and roosters of both hybrids. Gait problems have not been investigated to the same degree in broiler breeders as in broiler chickens, but a study by van den Oever *et al.* (2020) found impaired gait in broiler breeders to be rare, with severe gait problems in only 2.7% of the hens. The GS increased with age in our study, which was also found by van den Oever *et al.*, (2020). Across both hybrids, male GS remained relatively stable until 45 WOA and increased thereafter. For the roosters, but not the hens, there was an observed effect of hybrid, where the Hubbard birds had a higher GS. But it must be emphasized that the GS, even at the highest ages, were low compared to the prevalence reported in much younger broiler chickens. The causation of FPD is multifactorial, comprised of infectious, developmental and degenerative diseases, for impaired gait (Bradshaw *et al.*, 2002; Wideman, 2016). However, rapid growth rate and high bodyweight are considered the main underlying causes (Kestin *et al.*, 1992; Bessei, 2006; Knowles *et al.*, 2008). Due to restricted feeding, the breeders grow slower than the broiler chickens, which may explain the positive results in both hybrids in our study, even though the Hubbard hens are lighter than the Ross 308 hens. Severe FPD may lead to lameness in broiler chickens (Greene *et al.*, 1985). There was a positive correlation between footpad and GS for both hens and roosters, which is in line with Opengart *et al.* (2018) who found significantly greater odds of GS worsening as FPD worsened. This can be seen in our material as well, even though the GS and FPD scores overall were low.

The study found a correlation between light intensity and both FPD and GS. We hypothesized that more light would give more active birds and therefore better footpad health and GS. However, to our surprise, the statistics showed that brighter light led to worse FPD and GS. We do not know the rationale for this finding. This is the first-ever lifecycle study of broiler breeder FPD and GS, and light intensity as a risk factor should be investigated further.

All footpad evaluations were performed on the farm after manually brushing of dirt and litter. Evaluation and classification of FPD are easier to perform on the slaughter line after cleaning, compared to on farm (Martrenchar *et al.*, 2002). This may have affected the results, since it is more difficult to evaluate footpads before cleaning. Another important weakness of the study that must be considered is the relatively small sample size. Only eight flocks were included, four from each hybrid. Therefore, further studies should be performed to confirm the results found here. This is particularly necessary regarding the correlations between FPD/GS and the environmental risk factors assessed. It was not possible to perform these analyses by age, due to the low sample size (i.e. maximum four, but sometimes only three flocks visited per hybrid per age). For this reason, age is a confounding effect in these correlations that must be investigated further in future studies.

In conclusion, the results indicate that moderate and severe FPD are rare in the pullet period but increase with age in both Ross and Hubbard breeders. The prevalence of moderate to severe FPD was higher in the hens compared to roosters at the end of the production period and was strongly related to ammonia concentration in the house. Overall, lameness, as assessed by GS, was low in both hens and roosters.

Further studies are needed for both FPD and GS, to investigate causative factors.

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