

Foot Pad Dermatitis and Hock Burn in Broiler Chickens and Degree of Inheritance

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ABSTRACT A total of 2,118 birds from 2 strains were allocated to 12 groups of 93 to 100 each in 2 time-separated replicates. The development of foot pad dermatitis (FPD) and hock burn (HB) were recorded weekly from d 8 to slaughter on a set sample of live animals (7 per group). In addition, feet and hocks of all birds were investigated at slaughter at either 4, 6 (fast-growing strain), 8, or 10 (slow-growing strain) wk of age. Lesions were scored for both the left and right foot and classified according to a scale from 1 (no lesion) to 9 (very severe lesions) for FPD and from 1 (no lesion) to 3 (very severe lesions) for HB. No FPD lesions and very few low-grade HB lesions were found in chickens from the slow-growing strain. In the fast-growing strain, the first signs of FPD and HB were seen in wk 2. The incidence of both types of lesions increased thereafter. Foot pad dermatitis was more frequent

in females (49 vs. 36%, $P < 0.05$). Body weight did not affect FPD, but more HB were found at higher BW ($P < 0.01$). Egg weight influenced neither FPD nor HB. Variance and covariance components were analyzed using a multivariate animal model, in which scores for FPD and HB were transformed into logarithmic scale. The analyses were carried out using restricted maximum likelihood algorithm. Heritabilities were estimated to be 0.31 ± 0.12 (SE) for FPD, 0.08 ± 0.08 for HB, and 0.38 ± 0.13 for BW. Genetic correlations among these traits were low and nonsignificant. Phenotypic correlation between BW and FPD was low and nonsignificant and between BW and HB was 0.17 ± 0.05 ($P < 0.01$). The relative high heritability of FPD and the low genetic correlation to BW suggested that genetic selection against susceptibility to FPD should be possible without negative effects on BW gain.

Key words: broiler, plantar dermatitis, hock burn, heritability, genetic correlation

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INTRODUCTION

Foot pad dermatitis (FPD) is a type of contact dermatitis affecting the plantar region of the feet in poultry and other birds. At an early stage, discoloration of the skin is seen. Hyperkeratosis and necrosis of the epidermis can develop, and in severe cases, these changes are followed by ulcerations with inflammatory reactions of the subcutaneous tissue (Ekstrand et al., 1997). The lesions are commonly named “ammonia burns” and are thought to be caused by a combination of moisture, high ammonia content, and other not yet specified chemical factors in the litter (Berg, 2004). In some cases, this is a more predominant problem at high-stocking densities and in fast-growing strains (Tucker and Walker, 1992; Dawkins et al., 2004). Closely related to FPD are “hock

burns” (HB), in which the skin of the hock becomes dark brown. In severe cases, scabs are observed.

The FPD condition is an important aspect of poultry welfare that in severe cases can cause pain (Berg, 1998) resulting in unsteady walk (Harms and Simpson, 1975; Hester, 1994). Selection for rapid growth rate in broilers is accompanied by a decrease in walking ability, and there is a high unfavorable phenotypic correlation (0.8) found between BW and overall walking ability (Kestin et al., 2001). The FPD condition is a part of a general walking ability problem, but specific knowledge of genetic effects on FPD is very scarce.

In recent years, the level of FPD has been used to characterize the health and welfare of broiler flocks. Scores of foot health (FPD) have been imposed in the control of broiler health and welfare in Sweden and Denmark. They are used to regulate the management in broiler production toward principles in which FPD is reduced. The use of this model is under consideration in other countries and that is why FPD has become a subject of interest.

Two broiler strains differing in growth capacity and adult BW were compared. The size of the additive genetic variance component within the fast-growing strain

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Table 1. Descriptive variables of housing and feeding in relation to experimental block and strain¹

Variable	Block 1		Block 2	
	Ross 308	LB	Ross 308	LB
Group size (n)	80	80	100	93
Stocking density (birds/m ²)	8.4	9.5	10.5	11.1
Live weight at hatch (g; SE)	45 (0.6)	41 (0.4)	51 (0.8)	46 (0.6)
Live weight at slaughter ² (g; SE)	2,627 (55)	1,769 (39)	2,720 (53)	1,821 (38)
Feed energy content (kcal of ME/kg of DM)	3,248		3,177	
Feed protein content (% of DM)	24.8		23.6	

¹Ross 308 was a fast-growing broiler hybrid of Aviagen (Newbridge, UK); LB was a slow-growing dual-purpose experimental strain kept at the Danish Institute of Agricultural Science (Tjele, Denmark).

²Slaughtered at 6 wk (Ross 308) or 10 wk (LB).

was investigated, because an alleviation of this problem by conventional genetic selection would be dependent on genetic variation. Furthermore, the genetic correlation to other traits of commercial interest, such as BW, was studied.

MATERIALS AND METHODS

Experimental Design

Two identical experiments were carried out in 2 time-separated blocks, each in the same housing complex at Research Centre Foulum in Tjele, Denmark. The start of the first block was in October 2003, and the second block started in January 2004. A total of 2,118 broilers were housed in 12 groups per block. The FPD and HB conditions were investigated in 2 ways. Firstly, the development of lesions was followed over time, from d 8 to slaughter, by weekly recordings on a set sample of animals. Secondly, feet and hocks of all birds were investigated at slaughter at either 4 and 6 (fast-growing strain) or 8 and 10 (slow-growing strain) wk of age.

Animals, Housing, and Management

Two strains of chickens were used in the experiment: a fast-growing, conventional broiler hybrid (Ross 308) and a slow-growing dual-purpose strain (LB). The birds used in both blocks were obtained from the same parent stock kept at the research center, having an age of 32 and 46 wk, respectively, at collection of eggs. The parent stocks were kept in cages, and the hens were inseminated twice a week in a fully pedigreed system with 4 to 6 hens per cockerel applying the same mating partners for both blocks.

Lights were on in the house from 0700 to 2200 h. At hatch, the chickens were taken out of the hatchers such that 3 groups of equal numbers were identified according to the time of hatch; thus, group 1 was the first third part, group 2 was the middle third part (on average about 3 h later), and group 3 was the last third part (about 6 h later) of the chickens regarding hatch time. The chicks were individually identified according to the eggs they were derived from and wing-tagged and housed as-hatched in solid floor pens constructed with walls of wire-mesh on wooden frames. The stocking densities are given in Table 1. They varied slightly due

to hatch inconsistencies. The bottom 50 cm of the pen walls were made of plywood to prevent visual contact among groups, avoiding the risk of social facilitation of locomotor behavior among pens. The pens were positioned in the same room along 2 walls with a corridor in the middle. Each pen was bedded with wood shavings and equipped with 2 circular feed troughs with a diameter of 33 cm, each filled through a plastic tube from a hopper mounted on 3 legs above the center of the trough. Drinking nipples (8 or 9 per pen) were provided equidistant along water pipes running across the pens 124 cm from and parallel to the back wall.

During the first 3 d, additional feed was spread on lengths of paper placed underneath the drinking nipples to ensure that all chicks learned to associate the pellets with food. All groups were fed ad libitum using a conventional pelleted starter feed during the whole experimental period. Lights were on 24 h during d 0 and 1 in block 1 and d 0 to 2 in block 2. The extra day of full light in block 2 was chosen as these birds had an extended hatching period relative to the birds in block 1. In both blocks, a lighting schedule was applied, consisting of 30 min of dusk and dawn, respectively, surrounding 1 h of darkness from 2300 h until d 5, when the period of darkness increased to 8 h. From 13 to 28 d, a 4.5-h dark period was applied, and from 29 to 42 d, the dark period was 1.5 h. This was to comply with the lighting schedule specified in current Danish legislation for the raising of broilers. The room was heated by wall-mounted radiators. Ambient temperature and RH were measured every 2 h throughout the experiment (TH Trace, Dickson, Addison, IL). The room was heated before the beginning of the experiment so that the floor had reached 27°C before wood chip litter was applied in a 5-cm thick layer (2 kg/m²). The temperature was 33°C (at floor level) for the first 3 d and then gradually decreased to 21°C on d 28 and kept at this level until slaughter. Relative humidity was 20% on d 0 to 10 then gradually rose to 60% on d 40 and stayed there for the rest of the experiment.

Data Collection

Seven birds within each pen were randomly selected as focal animals. The foot pads and hocks of the focal animals were inspected the first time at d 8 and then inspected every week until slaughter at 6 wk (Ross 308)

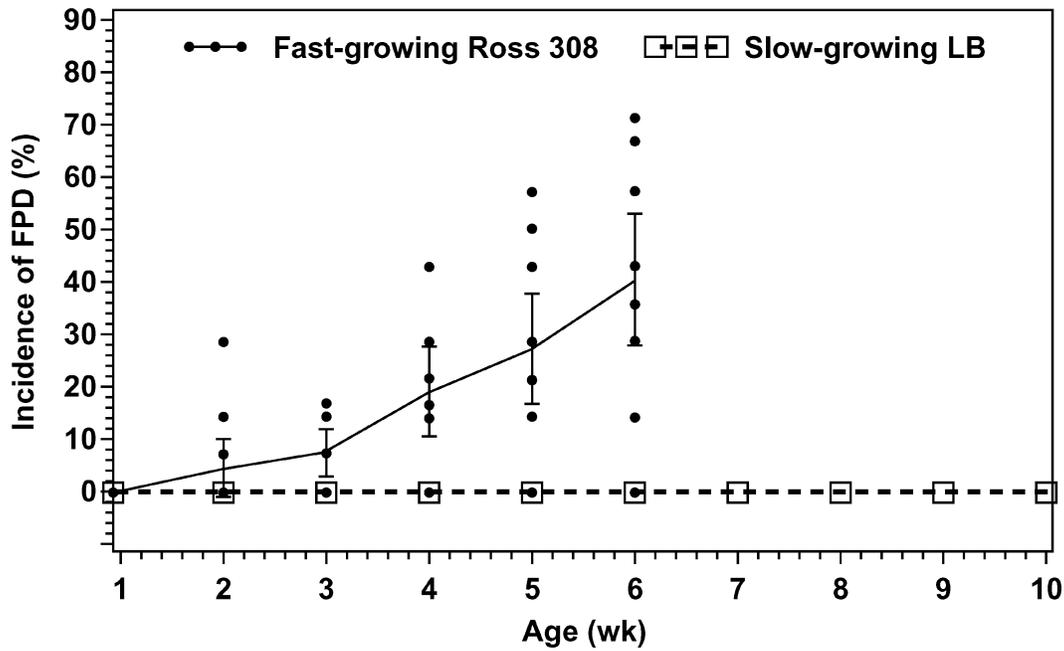


Figure 1. Percentage (± 2 SEM) of birds with foot pad dermatitis (FPD) during 6-wk (fast-growing Ross 308 strain) or 10-wk (slow-growing LB strain) growing periods. Points indicate each flock (pen) mean based on the average score of 7 focal birds. Full (Ross 308) and dotted (LB) lines indicate strain means.

or 10 wk (LB). Feet of any other chickens that died during the week were also scored. The feet of all animals were scored at 4 or 6 wk for Ross 308 (240 chicks per age) and at 8 or 10 wk for LB (228 chicks per age). The foot pads of both feet were scored. If the feet were dirty, they were gently washed with a wet cloth before scoring. Only the central plantar was scored. A scale from 1 (no lesions)

to 9 (very severe lesions) was used to evaluate degree of discoloration of papillae as well as the number and severity of scratches and wounds. The hocks were given 1 (not affected), 2 (color changes or minor lesions), or 3 points (severe lesions). Left and right hock were scored separately. The BW was recorded on an individual basis at the same time of scoring FPD and HB. Wing number,

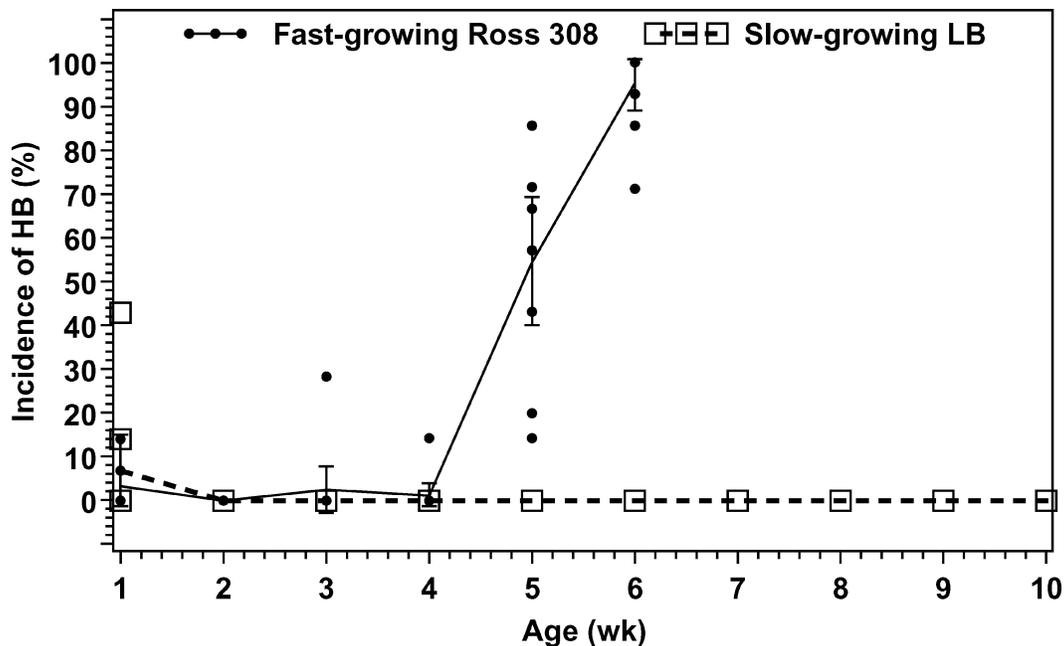


Figure 2. Percentage (± 2 SEM) of birds with hock burn (HB) during 6-wk (fast-growing Ross 308 strain) or 10-wk (slow-growing LB strain) growing periods. Points indicate each flock (pen) mean based on the average score of 7 focal birds. Full (Ross 308) and dotted (LB) lines indicate strain means.

BW, and age were recorded on all chickens that died during the experiment, and the cause of death was categorized as sudden death or a similar cardio-pulmonary problem, leg problem, or other problem.

Statistical Analyses

Both FPD and HB were recorded using multinomial scales, and the data analyses were carried out on the average score of both feet. Each calculated data point on FPD could thus be 1 of 17 values, and HB could be 1 of 5 values. However, in cases in which many cells would have been without observations if using the multinomial scale, data were transformed to a binomial scale. On this binomial scale, FPD scores 1, 2, and 3 were classified as no lesion (value = 0), and scores 4 to 9 as lesion (value = 1). The HB score 1 was classified as no lesion, and scores 2 and 3 as lesion. Data from live focal birds were analyzed on the binomial scale. Line differences were tested with the Wilcoxon nonparametric rank test for each week separately using the NPAR1WAY procedure of SAS (SAS Institute Inc., 1994). Data from slaughtered birds were analyzed on the transformed binomial scale as well as on the original scale. Binomial data were analyzed with the generalized estimation equation method (χ^2 distributed). The binary response was modeled as a logistic regression model using the explanatory variables block (1, 2), sex (male, female), hatching group (1, 2, and 3), BW, and egg weight. The analysis was conducted using SAS GENMOD procedure (SAS Institute Inc., 1994). Data for 4 and 6 wk were analyzed separately. Variance and covariance components for FPD, HB, and BW were estimated on original untransformed multinomial data. Only data for 6 wk of age in Ross 308 chickens were used, whereas the FPD and HB traits had no variation for chickens of the LB strain. A multivariate animal model was used in analyzing BW and log-transformed multinomial FPD and HB scores. The model for the analysis was

$$Y = \mu + \text{block} + \text{hatching group} + \text{sex} + \text{pen} + \text{additive genetic effect} + e \quad [1]$$

where Y = the multinomial score for FPD, HB, or BW; μ = intercept; block, hatching group, sex, and pen were treated as fixed effects; additive genetic effect was a random effect, and e = random residual. The analyses were carried out using the restricted maximum likelihood algorithm applying the DMV data analysis package (Jensen and Madsen, 1993).

RESULTS

Incidence of FPD and HB in the Focal Birds

No signs of FPD were found in chickens of the LB strain. In the Ross 308 strain, the first signs of FPD were seen in wk 2 and from then on they increased (Figure

1). The lesions were more severe in the fast-growing line at 3 ($Z = 2.73$, $P < 0.01$), 4 ($Z = 3.62$, $P < 0.001$), 5 ($Z = 3.92$, $P < 0.001$), and 6 wk ($Z = 3.92$, $P < 0.001$). The first sign of HB was seen in wk 1 in both strains. Only little HB (and only in Ross 308) was recorded in wk 2, 3, and 4. After wk 4, the incidence of HB sharply increased in Ross 308 (Figure 2). The lines differed at 5 ($Z = 4.22$, $P < 0.001$) and 6 wk ($Z = 4.24$, $P < 0.001$).

Incidence of FPD and HB in Birds Slaughtered at 4 Wk

Only birds from the Ross 308 strain had any damage to the foot pads or hocks at slaughter, and, therefore, only this strain was included in the following analyses. The incidence of birds with FPD was 78 of 455 birds at 4 wk (17%). The corresponding figure for HB was 0.5%. Due to the relatively low number of lesions at 4 wk, these data were not analyzed further.

Incidence of FPD and HB in Birds Slaughtered at 6 Wk

The incidence of birds with FPD was 185 out of 424 at 6 wk (44%). The corresponding figures for HB were 375 out of 424 birds at 6 wk (88%). In addition to the large difference in FPD among strains, there was also a large variation among paternal half-sib groups within the fast-growing strain. The frequency of lesions was calculated from paternal half-sib groups with a minimum of 5 birds. The frequencies of FPD in half-sib groups ranged from 0 to 100% (Figure 3), and the frequencies of HB ranged from 50 to 100% (data not shown). Because the half-sibs were distributed over 7 pens (on average), ranging from 2 (2 sires) to 12 pens (3 sires), the variation among half-sib groups reflected a genetic variation in incidence of FPD and HP.

The FPD incidence was more frequent in females than males (lsmeans of 49 vs. 36%; $df = 1$; $\chi^2 = 13.23$; $P < 0.001$). There was a higher frequency of FPD in the second block (52 vs. 33%; $df = 1$; $\chi^2 = 8.48$; $P < 0.01$). Incidence of FPD tended to be more frequent in hatching group 2. Body weight did not influence the frequency of FPD, but it affected the incidence of HB with more HB at higher BW ($Z = 3.14$, $P < 0.01$). Egg weight influenced neither FPD nor HB. Fixed effects of block, sex, and hatching group were quite similar when analyzed using the log-transformed multinomial scale, although the contrast among blocks was not significant, whereas some of the contrasts among hatching groups were (Table 2).

Genetic Parameters of FPD, HB, and BW

Estimates of heritability for FPD and HB score (average of both feet) and BW at 6 wk are given in Table 3. The estimates of heritability were moderate for BW and FPD but low for HB. Genetic correlations among these traits were nonsignificant. Phenotypic correlations between BW and HB and between FPD and HB were low

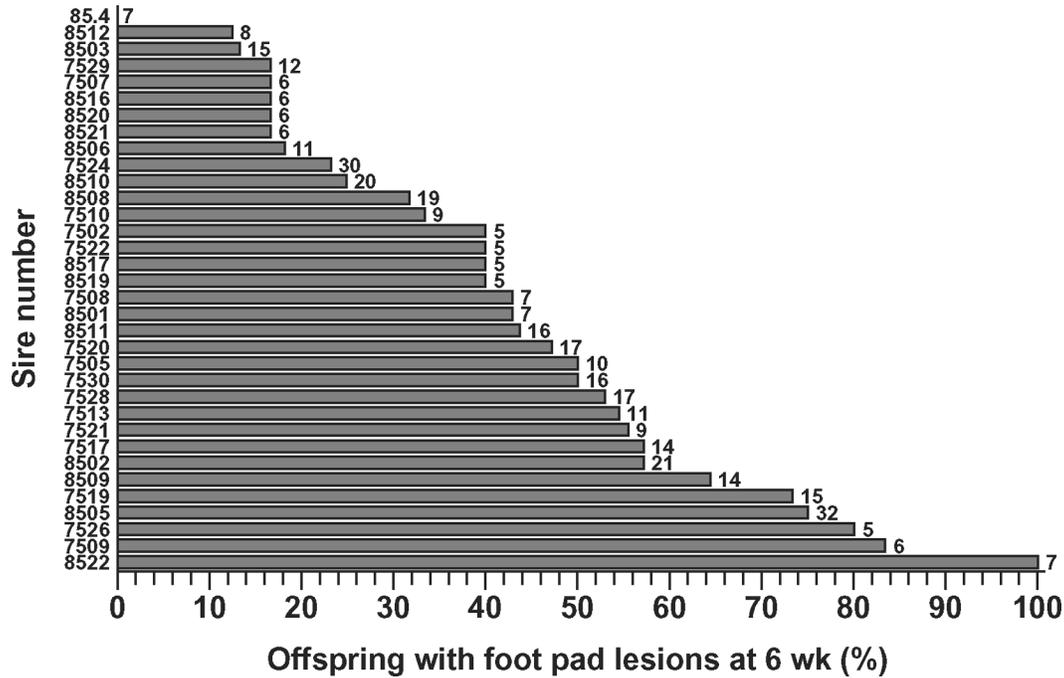


Figure 3. Percentage of offspring with foot pad dermatitis for the individual sires in the fast-growing strain recorded at slaughter at 6 wk of age. The number to the right of each bar is the number of offspring per sire. Only sires with a minimum of 5 offspring were included.

but significantly different from 0. The estimates of phenotypic and genetic correlations between FPD and BW were not significantly different from 0.

DISCUSSION

Development of Lesions Over Time

The increase in FPD over time in the present experiment was less rapid than that found by Martland (1985) in an experimental group, in which the litter was sprayed twice weekly with water (but more rapid than in their control group in which no water was applied). The frequency of birds with HB reached twice the level (40%) as that of FPD but differed by being evident after 4 wk and then increasing very rapidly, whereas the incidence of FPD steadily increased from wk 2 to 6. This result was in agreement with that described by Greene et al. (1985), in which FPD developed sooner than HB (at 19 vs. 22 d). However, in the study by Greene et al. (1985), FPD

reached a higher level than HB (98 vs. 88%) at 36 d. In contrast to the present investigation, Sørensen et al. (2002) found a higher degree of FPD in birds slaughtered at 33 to 35 d compared with 35 to 45 d.

Genetic Effects

The estimate of heritability for the risk of developing FPD is a new and exciting finding. The magnitude of the estimate (0.31) indicates that it should be possible to decrease the incidence of FPD by genetic selection. Moderate heritability together with large phenotypic variation indicates a large genetic variation in FPD. Another important finding in this respect is the low genetic correlation with BW (close to 0). This indicates that selection against FPD can be expected not to influence BW greatly. In addition, selection for higher BW may not affect the genetic susceptibility to develop FPD.

The biological mechanism behind this genetic variation in FPD could be related to biotin, a functional constituent

Table 2. Effects of block, hatching group, and sex on BW, foot pad dermatitis (FPD), and hock burn (HB) scores in the observed scale at 6 wk of age¹

Effect	Contrast	FPD	HB	BW
Block	Block 1 vs. 2	-0.031 ± 0.224	0.213 ± 0.182	0.068 ± 0.043
Hatching group	Time 1 vs. 2	0.224 ± 0.216	0.387 ± 0.180*	0.007 ± 0.042
	Time 1 vs. 3	-0.362 ± 0.206	-0.060 ± 0.169	-0.046 ± 0.039
Sex	Time 2 vs. 3	-0.585 ± 0.251*	-0.447 ± 0.204*	-0.053 ± 0.045
	Male vs. female	-0.268 ± 0.114*	0.384 ± 0.093**	0.439 ± 0.026***

¹The effects for FPD and HB were obtained by inverse transformation from those in log-transformed multinomial scale.

* $P < 0.05$, ** $P < 0.01$, and *** $P < 0.001$.

Table 3. Heritability estimates (on the diagonal) and genetic (above the diagonal) and phenotypic correlations (below the diagonal) \pm SE in Ross 308 chickens for foot pad dermatitis (FPD), hock burn (HB) scores (logarithmic scale), and BW at 6 wk

Trait	FPD	HB	BW
FPD	0.31 \pm 0.12**	-0.40 \pm 0.49	-0.08 \pm 0.26
HB	0.14 \pm 0.05**	0.08 \pm 0.08	0.44 \pm 0.42
BW	0.04 \pm 0.05	0.17 \pm 0.05**	0.38 \pm 0.13**

** $P < 0.01$.

of various enzyme systems. Families susceptible to FPD may have a perturbed uptake function as marginal nutritional deficiencies of biotin in practical diets have been associated with foot pad lesions in broilers and turkeys, respectively (Harms and Simpson, 1975; Harms et al., 1977). Alternatively, a genetic variation of gut physiology influencing gut microbial flora could be an explanation. Inoculation with *Lactobacillus acidophilus* causes an increased incidence of FPD of chickens, presumably by competing with the chicken for dietary biotin (Buenrostro and Kratzer, 1983). The mechanism of depositing biotin in the egg can be important. Biotin supplementation of breeder hens results in an increase in biotin level in eggs and a decrease of FPD in the progeny (Harms et al., 1979). Genetic variation in biotin deposition might in part contribute to genetic variation in FPD found in the present experiment.

The estimate of heritability for developing HB was low and not significantly different from 0. In the present study, HB was scored as 3 grades, compared with 9 grades for FPD. Estimate of heritability for a variable such as HB was expected to be lower than the heritability of the underlying susceptibility to develop HB. A threshold model may improve the estimation of heritability for HB. We were unable to find any reports on estimates of heritability of HB. It is difficult to say what could be expected, because the relation between FPD and HB is not straightforward. In the present study, there was a positive phenotypic correlation and a negative, although nonsignificantly different from 0, genetic correlation between FPD and HB. In other experiments on FPD and HB in broilers, negative phenotypic correlations have been found (P. Sørensen, Tjele, Denmark, unpublished data).

Effect of Other Factors

The FPD condition was more frequent in females. There are contradicting results in the literature on this point, with studies finding more FPD in males (Harms and Simpson, 1975), no difference between sexes (Berg, 2004), or more FPD in females (Harms et al., 1977; P. Sørensen, unpublished data). In the unpublished data of Sørensen, a higher level of FPD was accompanied by a lower level of HB and vice versa. In the present study, BW did not influence the frequency of FPD. A higher incidence of HB was found for birds with higher BW. This is in accordance with Sørensen et al. (2000), who found a correlation of 0.27 between HB and BW on 5-wk-old Ross 208 chickens.

It might be that heavier birds tend to sit more on the hocks compared with lighter birds that in turn stand relatively more. The effect of hatching group on FPD and HB was not quite clear, and we were not able to find any earlier publications describing this effect on FPD and HB in broilers or other poultry species. Blocks affected FPD significantly only when using the incidence of FPD rather than the multinomial scale. Many factors, including the age of the parent stock, were included in the block effect, and it is not possible to separate these or to explain the discrepancy between analyzing incidence vs. multinomial scores.

In conclusion, the 2 most frequently identified remedial measures in relation to welfare problems in general in domestic animals involves developing practical improvements to the animal housing and management system and increasing the ability of the animal to adapt to its environment. In the case of FPD and HB, improving the environment (i.e., the litter quality) has been the main focus of research. The possibility of changing the genetic-based susceptibility to these conditions has not yet been investigated, although genetic selection on production performance might be contributing to the problem. The estimates of heritability of FPD and HB presented here are, as far as we know, the first to be reported in the literature. The relatively high magnitude of the heritability of FPD and the low genetic correlation to BW suggest that it is possible to reduce susceptibility to FPD by genetic selection without negative effects on BW gain. This makes the trait more likely to be included in selection indices, which would be of benefit to broiler welfare worldwide.

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