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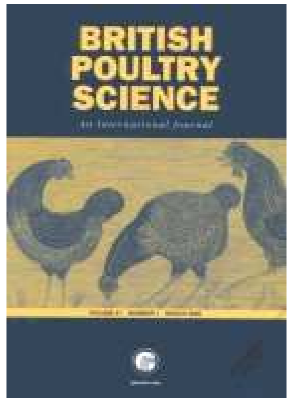

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Factors affecting the prevalence of foot pad dermatitis, hock burn and breast burn in broiler chicken

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Running head : HUSBANDRY AND BROILER CONTACT DERMATITIS

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Absract. 1. Standardised data on flock husbandry were recorded on 149 broiler farms during the 4 days prior to slaughter.

2. Birds were examined at the slaughterhouse for contact dermatitis lesions. Foot pad dermatitis score (FPDS) and hock burn score (HBS) were measured on five point scales. Carcase rejection data were also collected.

3. The mean percentage of birds in each flock with: moderate or severe foot lesions was 11.1% (range 0% - 71.5 %); moderate or severe hock burn was 1.3% (range 0% - 33.3%); and, breast burn was 0.02%.

4. A general linear model was developed to examine factors associated with mean flock FPDS. Assuming a linear relationship, within the range of data collected and with all other factors remaining the same, every 1% increase in the proportion of Genotype A birds in the flock was associated with an increase in mean FPDS of 0.003, every 1-point increase in litter score was associated with a 0.326 increase in mean FPDS and every 1-point increase in flock mean HBS was associated with a 0.411 increase in mean FPDS. Flock mean FPDS was associated with feed supplier and was higher in winter.

5. The general linear model developed for flock mean HBS, found that every 1-point increase in mean FPDS increased mean HBS by 0.090, every 1-point increase in litter score increased HBS by 0.119 and, every 1% increase in small/emaciated birds decreased mean HBS by 0.333. Reduced HBS was also associated with increased final litter depth, younger slaughter age and an increased percentage of dietary wheat. For every 1% increase in Genotype A birds, a decrease in flock mean HBS of 0.003 would be expected.

6. An effect of hatchery was also identified.

INTRODUCTION

Contact dermatitis is an ulcerative condition of the skin affecting the plantar surface of the feet (foot pad dermatitis), the hock (hock burn) and the breast (breast burn). All conditions may occur together in a single bird. Contact dermatitis lesions are thought to be caused by a combination of litter moisture and the chemical burning effect of ammonia from urea in the litter (Tucker and Walker, 1992; Gordon and Tucker, 1993) and are therefore likely to cause pain, as a result of tissue trauma, the degree of which will vary with lesion severity. In addition, there is some evidence that the incidence and severity of contact dermatitis may reflect litter and air quality in the house over the flock cycle, thus reflecting welfare aspects other than pain (Martland, 1985; Tucker and Walker, 1992). For this reason, the incidence and severity of contact dermatitis may be used as a welfare assessment measure in commercial broiler production systems in the UK, either by individual companies or by accreditation schemes, such as (RSPCA, 2002). Currently hock burn lesions, rather than foot or breast burn, are routinely measured and recorded in the UK.

In the Swedish broiler industry, incidence and severity of foot pad dermatitis are measured routinely for all flocks and the scores used to determine permitted stocking density on farm, as part of the Swedish Care Program (Ekstrand *et al.* 1998). For this Program, the maximum permitted stocking density may be abated, for subsequent flocks in a house, in response to a combined measure of the incidence and severity of foot pad dermatitis in birds from the house, as measured at the processing plant. The poorest-performing farms are limited to stock at 20 kg per m^2, whereas the best are permitted to stock at 36 kg per m^2, with gradations between these (Ekstrand *et al.* 1998). The provisions of the current draft of the proposed EU Broiler Directive are based on the Swedish Care Program and include, among other provisions, a requirement for the measurement of the incidence and severity of foot pad dermatitis at processing plants, which would then be used to determine permitted stocking density of birds in subsequent flocks on farm.

Factors affecting the incidence and severity of contact dermatitis for a broiler flock have been reviewed by Bray and Lynn (1986) and by Tucker and Walker (1992). These authors concluded that hock, foot and breast burn are primarily affected by: drinker design; feed composition (including fat and protein quality and inclusion rates, and salt content); house temperature and relative humidity, as affected by provision of heating, ventilation system specification, design and operation and thermal quality of wall and ceiling materials; litter type and quality; floor permeability; and stocking density. The effect of leg weakness on contact dermatitis lesions was not examined in these studies. However, a high incidence of leg weakness was weakly but significantly correlated with increased hock burn and foot pad dermatitis in two later studies (Sorensen and Kestin 1999; Su *et al.* 1999). The use of very shallow litter has been shown to produce dry litter (von Wachenfelt 1993) through aeration by birds and to reduce footpad dermatitis (Ekstrand *et al.,* 1997). Deficiencies in some micronutrients, including biotin, zinc, copper, molybdenum and sulphur-containing amino acids, have been shown to increase contact dermatitis by various authors, reviewed by Haslam (2003), and may account for the finding that feed supplier has been found to be correlated with the incidence and severity of hock burn (McIlroy *et al.,* 1987) and foot pad dermatitis (Ekstrand *et al.,* 1998). Thus, there is evidence that the incidence and severity of contact dermatitis may reflect many aspects of bird welfare, as well as being a direct source of pain, and so may indeed be a valid assessment measure for broiler welfare.

The prevalence of footpad dermatitis in the Swedish broiler flock has been determined (Ekstrand *et al.* 1998) and incidence and severity of breast burn and hock burn in commercial flocks in Northern Ireland recorded, before and following an incentive scheme for farmers to reduce hock burn levels (McIlroy *et al.,* 1987; Menzies *et al.,* 1998). However, the incidence and severity of these contact dermatitis lesions in the UK was not known, with the consequence that the effect of the draft Broiler Directive on the UK broiler chicken industry could not be predicted. Furthermore, previously, there was insufficient scientific evidence of the extent to which incidence of contact dermatitis, recorded at the processing plant, reflect leg health and bird welfare or how various aspects of husbandry on farm affect contact dermatitis. Existing studies, discussed above, were scant, several were old and many were not relevant to current bird genotypes and contemporary husbandry systems or were based on studies in European countries other than the UK, where husbandry systems, bird stocking densities and slaughter weights often differ from those usual in the UK broiler industry. In addition, experimental studies on contact dermatitis are not always directly relevant to birds in commercial conditions.

This paper reports on a study to determine the incidence and severity of contact dermatitis lesion in the UK broiler flock, measured at the processing plant, and examines the effect of various aspects of flock health and husbandry on these.

MATERIALS AND METHOD

This study made use of some of the data collected for a large on-farm, epidemiological study of broiler leg health (Knowles *et al.,* 2007). Five major UK broiler companies took part in these studies: these companies allowed access to any of their contract or company farms and to their processing plants. A random selection of farms was surveyed. The 5 companies supplied full lists of their farms and flock visits by assessors were randomised to farms and to a unit within the farm. The number of farms visited per company was weighted by the number of birds produced by each company. The survey unit was a flock of birds within a growing house within a farm: a total of 206 visits were made to each of 206 flocks, which were timed to occur within 4 d of slaughter.

Farm data were collected by veterinary surgeons with postgraduate qualifications in Poultry Medicine and Production or Welfare Science, Ethics and Law. The survey team was comprised of 18 veterinary surgeons from a wide variety of backgrounds. To ensure standardisation of assessment and data collection a formal, 5-d, training course was established. The course included training on completion of on-farm assessment forms and assessment of bird gait. Training in gait scoring was by means of on-farm visits and video training sessions. The veterinary surgeons were continually assessed during the training course until they had developed a uniform scoring technique. At the end of the course, average scores given by all the assessors for video clips of 100 lame birds, for each 'gait score', were within half a score. During the main phase of the survey, which took place over a period of 18 months, assessors were sent, at approximately 6 and 12 months, a tape containing video sequences of the range of gait scores. The scoring of the tapes was monitored to ensure that the assessors remained standardised (Knowles *et al.* 2007).

Each farm visit consisted of 4 main stages: completion of an epidemiological recording form, with the assistance of a representative of the farm, which provided a description of the farm, house and flock; assessments made by the recorder alone; assessment of the gait score of 250 birds, selected at random, within one house; and, selection of 10 birds for *post mortem* examination.

The on-farm recording form consisted of 134 questions and included: parent flock information, including genotype/strain, health history and age; hatchery information, including hatchery, distance and time transported and hatchery chick vaccination programme; general information including number and weight of chicks placed, sex, time of year, age at assessment and slaughter; specific husbandry practices including stocking density and thinning practice; brooding conditions; a detailed nutritional profile, including type of feed (pellet or meal) and fibre, vitamin and mineral content in each of the feeds provided; litter substrate; feeder and drinker design and type; lighting programme; house age and construction details; target temperature and ventilation profiles; water source; and, vaccination programme, coccidiostats used, diseases diagnosed during the flock cycle and medication history. During this visit information on flock performance was collected, including growth profile from weekly weighings, weekly mortality pattern and weekly cull patterns, categorised by cause for culling, including culling for leg weakness. Background information about the management of the flock, was also recorded, including: bird:stockperson ratios; age and broiler growing experience of stock people and their training and qualifications; background information about the site and company, including size of sheds, number of birds on site; and, types of biosecurity measures in place. Fifteen additional assessments were made by the recorder alone, covering aspects such as air quality, cleanliness and feed quality. Air quality, cleanliness and feed quality were assessed on 4-point simple descriptive scales. Two hundred and fifty birds were gait scored within the house, selected at random, by reference to a pre-randomised location identifier. Birds were selected from 10 locations, in groups of 25 to 30, by corralling at each location using a hinged catching pen. Each bird was individually encouraged to walk out of the pen and was scored as it did so (Knowles *et al.* 2007). At each location, litter quality was assessed by the method described by (Tucker and Walker 1992) on a Numerical Rating Scale of between 1 (dry and crumbly) and 5 (capped and wet). Eight lame and two sound birds were selected, killed using intravenous barbiturates and weighed prior to *post mortem* examination.

Of the 206 flocks visited on farm, 149 were scored for contact dermatitis lesions at the processing plant. Three observers were trained to record levels of foot pad dermatitis and hock burn by standardised methods, using 5-point scales: scores given on these scales were termed the Foot Pad Dermatitis Score (FPDS) and Hock Burn Score (HBS) respectively. The photographic system used for the collection of foot pad dermatitis was that used routinely by the Division of Farm Animal Science at the University of Bristol and that used to collect hock burn data was that used routinely at the Agricultural Development and Advisory Service (ADAS), Gleadthorpe, (Tucker and Walker, 1992).

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A breast burn recording system was not developed as very few lesions were seen during pilot visits to plants. For the final plant visit protocol, the period assigned to breast burn recording was reduced, from a total period per flock of 15 min to a total period of three minutes, all birds passing the assessment point during the assessment period were assessed, rather than a subsection as for hock burn and foot pad dermatitis: breast burn was recorded as either as “absent” or “present”.

The three plant data observers were standardised for recording contact dermatitis lesions during a number of pilot plant visits. The degree to which the observers were in agreement was examined statistically, by calculating the Coefficient of Concordance (Kendall’s *W*), where 0 indicates no agreement and 1 indicates complete agreement. Agreement for foot pad dermatitis and hock burn recording, on a 3-point scale was poor during three pilot visits while agreement for recording on the 5-point scale was good. The 5-point FPDS for foot pad dermatitis recording and the 5-point HBS for hock burn recording, discussed earlier, were therefore adopted for data collection for this study. Several standardisation and re-standardisation visits were made between November 2002 and March 2003. For these trials, Kendall’s *W* was found to range between 0.55 and 1.0, but with most values between 0.8 and 0.9.

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For the final protocol, the standardised recorders conducted three recording cycles, scoring foot pad dermatitis lesions and hock burn lesions for 5 min, for a proportion of birds passing the inspection point immediately after bird defeathering at the processing plant. The recording periods were made near the beginning, at the end and in the middle of the flock to ensure that the samples taken were representative of the whole flock and not just one part of the flock or loading cycle. A proportion, selected at random, of the birds passing the observation point in the allocated time was assessed, because the speed of the line precluded assessment of every bird. The total number of birds with each lesion score was expressed as a percentage of the total number of birds assessed, as the total number of birds assessed in the time allocated varied with line speed and lesion distribution (if most birds had lesion scores 0, for example, the speed of assessment was greater than where the lesion scores were more varied).

Breast burn lesions were assessed immediately after bird defeathering for all birds for a period of one minute, for three different periods. The line speed was then calculated by measuring the number of birds passing the observation point during one minute. The total number of birds with breast lesions was expressed as a percentage of the total number of birds assessed, which was calculated using the line speed.

When the entire flock had been processed, the recorder collected the Meat Hygiene Service (MHS) carcase rejection data recorded by MHS personnel on the plant, including the total number of carcases rejected, the number of birds found Dead on Arrival (DoAs) and the number birds classified as small or emaciated.

Data analysis

For each flock, contact dermatitis data collected at the processing plant was converted to a percentage of the total birds assessed, for hock burn, foot pad dermatitis and breast burn. The mean, standard error and range of levels of each class of contact dermatitis, were calculated. The Kolmogorov—Smirnov test statistic was calculated for flock mean FPDS and HBS, to test for normality of frequency distribution.

Several measures of stocking density were calculated, including: stocking rate (birds placed per square metre); Biological Load Index (BLI) (stocking rate minus mortality x weight at kill); stocking density (bird weight per square metre) at age of inspection; stocking density at kill; projected stocking density at kill on the day of the farm visit; stocking density prior to each thinning; average stocking density prior to thinning; and, highest stocking density throughout flock cycle. These were calculated using recorded or predicted weights and bird numbers at the specific times during the flock cycle, recorded during the farm visits. Predicted weights were calculated using standard growth curves. Bird numbers were adjusted according to mortality figures and birds removed during previous thinnings, as recorded on house records. The utility and accuracy of using BLI in analysis of these data is discussed later.

The average litter quality score was calculated as the mean of the individual litter scores.

Scatterplots were first examined for all correlations in order to check for non-linear relationships between the variables. Bivariate correlations were carried out between each class of contact dermatitis and: each measure of stocking density; bird weight and age; mean gait score of the birds assessed by the veterinary assessor; and, mean litter quality score. The Spearman's rho statistic was calculated for each significant correlation, to give an indication of the strength of all significant associations.

Finally, the plant data were analysed in conjunction with data gathered during farm visits. Univariate general linear models were constructed to determine the aspects of house specification and flock husbandry which accounted for most of the variability found in the data affecting incidence of flock mean FPDS and HBS. Variables were entered into the model pre-selected on the basis of the bivariate correlation results and retained if $P \leq 0.05$. The procedure was stepwise and P-values of 95% or greater were accepted as significant.

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From the model developed, the effect on each lesion score of a change in each variable included in the model, for an otherwise average flock, was calculated. This was done by first calculating the sum of the variable weightings in the model to give the f value. The difference between the f value in the model and the f value for an increase in that variable by one unit (the weighting of each variable), was then calculated to give the change in lesion score which would result from a change in each variable of 1 unit, expressed in the units used in development of the model.

Hock burn and foot pad dermatitis were recorded by trained, standardised observers for 149 flocks. Data were collected from 8 different slaughter plants belonging to 5 different companies, between September 2003 and March 2005, regularly throughout the year: visits were suspended between the end of the standardisation period, February 2003, and September 2003 due to the risk of spreading avian influenza and a heat wave. Foot pad dermatitis, hock burn and breast burn data were collected from approximately 149 000 birds.

RESULTS

Descriptive statistics and distribution frequencies

The mean, standard error and range of each class of contact dermatitis are summarised in Table 1. Thus, for the UK flocks studied, the mean percentage of birds with moderate (FPDS 3) or severe (FPDS 4) foot lesions was 11.02%, ranging from 0% to 71.51%. The mean percentage of the flock found to have moderate or severe hock burn was considerably less, at 1.29%, ranging from 0% to 33.33% while the mean percentage of the flock found to have breast burn was very small, at only 0.02%.

The frequency distributions for flock mean FPDS from this study and the flock mean HBS are presented in Figures 1 and 2.

Bivariate correlations

The Kolmogorov—Smirnov test statistics for foot pad dermatitis, hock burn and breast burn, and most other variables, were greater than 0.210 and were significant, indicating that they did not have normal distributions. It was therefore necessary to use nonparametric tests for testing for correlations between variables, which do not make distributional assumptions (Petrie and Watson 1999). The significant bivariate correlations between flock mean FPDS and HBS with the different measures of stocking density, bird weight and age, and litter quality are presented in Table 2. The Spearman's rho statistic, for analysis of bivariate correlations between nonparametric variables, is presented for each significant, or close to significant, correlation.

Flock mean FPDS and HBS were very weakly, and close to significantly correlated, in this study, although each of these contact dermatitis measures showed significant or very significant correlations with different variables. Flock mean FPDS had a fairly strong, and very significant, positive correlation with litter quality and was weakly, positively correlated with stocking rate. Mean flock HBS was not correlated with either of these variables, but did have very significant correlations with other variables, including strong and fairly strong positive correlations with live weight and age at slaughter and a very significant, weak correlation with BLI: flock mean FPDS was not correlated with these variables. Flock mean HBS was weakly or very weakly negatively correlated with many other measures of stocking density, which was an unexpected finding. There was a fairly weak, very significant positive association between birds that were DoA at the processing plant and flock mean HBS and a very weak, significant positive association between total carcase rejection rate and flock mean HBS: neither of these variables was associated with flock mean FPDS. Mean bird gait score was weakly associated with flock mean HBS but was not associated with FPDS.

Univariate general linear model

The GLM Univariate procedure provides regression analysis and analysis of variance (ANOVA) for one dependant variable by one or more variables. ANOVA calculations are robust for departures of a variable from a normal distribution. Inspection of the residuals from the models developed for flock mean FPDS and HBS indicated that these variables could satisfactorily be treated as continuous. The univariate model developed to account for the variability in the data with respect to flock mean FPDS is presented in Table 3.

Thus the percentage of birds that were Genotype A, the average litter score, feed supplier, HBS and the season of the year accounted for 36.6% of the variability in flock mean FPDS between farms. The equation for the univariate general linear model for flock mean FPDS is:

FPDS = -0.806 + 0.003 GENOTYPEA + 0.360SAMPLEDL + 0.387 FEEDSUPPLY +
0.411 HOCKSC + 0.150 SEASONS + 0.221 SEASONC ....

The model was based on data in which the percentage of Genotype A birds ranged between 0% and 100%, mean litter scores ranged between 1 and 4.9 and mean flock HBS ranged between 0% and 1.8%. From this model, assuming a linear relationship, all other factors constant, an increase in percentage Genotype A birds of 1% will result in an increase in mean FPDS of 0.003, an increase in litter score of 1.0 will result in an increase in mean FPDS of 0.360 and an increase in mean HBS of 1.0 will be associated with an increase in mean FPDS of 0.411. Feed supplier was also associated with foot pad dermatitis score, such that integrated, rather than independent, suppliers were associated with an increase in mean FPDS of 0.387, although this was strongly associated with one independent supplier which supplied just one of the companies and so could be confounded. The model also identified a significant seasonal variation in incidence of foot pad dermatitis, which could account for up to 5% of variation in flock mean FPDS and which was not identified using the bivariate correlations, due to the cyclical nature of the seasonal effect. The incidence of foot pad dermatitis was significantly higher in the winter than in the summer.

The univariate model developed to account for the variability in the data with respect to flock mean HBS is presented in Table 4. Thus, the percentage of birds which were Genotype A , percentage of wheat in diet 3, bird age at slaughter, foot pad dermatitis score, final litter depth, percentage of birds which were classed by the MHS as small or emaciated birds, average litter score, and the hatchery of origin, accounted for 56.0% of the variability in mean HBS between flocks. The equation for the model for flock mean HBS is:

HBS = -0.887 – 0.002 GENOTYPEA – 0.022 WHETDT3 + 0.037 AGEATSLA + 0.090 FOOTSCOR – 0.015 FNLTDPTH – 0.333 RC6 + 0.119 SAMPLEDL + 2.459 HATCHERY

The model was based on data in which the percentage of Genotype A birds ranged between 0% and 100%, the percentage of wheat in diet 3 ranged between 0% and 30%, age at slaughter ranged between 33 days and 58 days, average FPDS ranged between 0 and 3, litter depth ranged between 1cm and 20cm, percentage of small or emaciated birds ranged between 0% and 2.15% and litter scores ranged between 1 and 4.9. From this model, assuming a linear relationship, an increase in average FPDS of 1.0, within an average flock, will result in an increase in flock mean HBS of 0.090, an increase in litter score of one will result in an increase in flock mean HBS of 0.119 and, for every percentage increase in birds which were classed by the MHS as small or emaciated birds, a decrease in flock mean HBS of 0.333 would be expected. Similarly, for every centimetre increase in final litter depth, within an average house, a decrease in average flock mean HBS of 0.0.015 would be expected, an increase in age at slaughter of one day will result in an increase in flock mean HBS of 0.037 and an increase in the percentage of wheat in diet 3 of 1% will result in a decrease in flock mean HBS of 0.022. For every percentage increase in Genotype A birds, within a house, a decrease in flock mean HBS of 0.003 would be expected. This model also identified an effect of the hatchery from which the chicks were derived on flock mean HBS, with each hatchery having a different degree of effect.

DISCUSSION

The mean flock percentage of moderate plus severe foot pad dermatitis lesions found in this study was 11.02%, ranging from 0 to 71.51%. This is very similar to that found in Swedish flocks, by Ekstrand *et al.* (1997), who also quantified foot pad dermatitis of birds at the slaughter plant and found the mean prevalence of mild and severe lesions to be 38%. However, these studies were carried out in Swedish flocks over 10 years ago (in 1994 and 1996) and husbandry conditions and bird genotypes may have differed from those examined in this current study. In particular, it is uncommon for flocks to be thinned in Sweden (Ekstrand, personal communication).

A very recent study of UK flocks, measured at two processing plants, found that the prevalence of foot pad dermatitis was twice as high in flocks from one of the plants than from the other (Pagazaurtundua and Warriss, 2006). However, for their study birds were taken from only two plants and collected from one plant in September and October, and from the other in June, July and August, the authors therefore concluded that the results may not be representative of the whole UK broiler flock. They suggested 18.1% as an initial indication of the overall incidence of foot pad dermatitis in UK broilers, with 10.2% being scored as 3 or 4 on the 4-point scale used in their study.

The flock mean percentage of moderate plus severe hock burn lesions found in this current study was 1.29%, ranging from 0 to 33.33%. This is low in comparison to that reported for flocks in Northern Ireland by McIlroy *et al.* (1987), of 21% and by Menzies *et al.* (1998), of 7%, although, for these studies, hock burn was measured on a two-point scale (0 or 1) and it is unclear whether very mild or mild lesions were scored as 0 or 1. All of these studies recorded the hock burn incidence of birds at the slaughter plant. However, details of the scale(s) used were not reported.

The flock mean percentage of birds with breast burn lesions found in the current study was 0.002%, ranging from 0 to 0.12%. This is very low in comparison to that reported by McIlroy *et al.* (1987), of 0.3%, and by Bruce *et al.* (1990), of 0.2%, but similar to that found by, Menzies *et al.* (1998), of 0%, in flocks in Northern Ireland. No ranges were reported for these studies.

However, it is possible that the flocks examined for this study may not completely reflect the full cross section of UK poultry flocks. For example, the Broiler Production Companies collaborating with this project volunteered to do so rather than being selected at random, and they therefore may represent those companies with a more positive interest in broiler health and welfare. Farmers supplying these companies might therefore receive both more information concerning preventative health strategies, and more encouragement to use them, than farmers supplying companies which were not involved with this project. There exists, therefore, the possibility that the results presented for this study may underestimate the incidence of hock burn and foot pad dermatitis in the UK boiler industry. However, the sample taken for this study was selected at random from 5 of the largest broiler production companies in the UK, which between them slaughter an estimated 420 million birds annually (Cook, personal communication 2006), and therefore represents approximately 50 per cent of the UK's annual production of broiler chicken, estimated in 2004 to be 805 million birds (Leidahl 2005).

The positive bivariate correlation found between flock mean FPDS and litter quality is unsurprising, as it might be expected that poorer litter quality would result in an increase in contact dermatitis. Similarly, the correlation found between flock mean FPDS and stocking rate is expected, as a greater density of birds would be likely to cause poorer litter quality due to the production of a greater volume of faeces, with a resulting increase in contact dermatitis. However, where flocks have been thinned, a very common procedure in the UK, such an association is not as clear cut as it would depend on how long before slaughter a house was thinned and on how rapidly, post thinning, litter quality improves and lesions heal, if at all.

Live weight and age at slaughter and BLI are likely to co-vary, which accounts for them all having significant positive correlations with flock mean HBS (see Table 2). This covariance may also account for the fact that neither BLI nor bird weight appeared in the univariate linear model developed to account for the variation in flock mean HBS, discussed below, while bird age did. Clearly as bird age at slaughter increased, so weight and BLI increase, so age accounted for a large part of the variation of all of these variables.

The negative correlation of some other measures of stocking density with flock mean FBS may appear, superficially, to be counterintuitive, because it might be expected that greater density of birds would be likely to cause poorer litter quality with a resulting increase in contact dermatitis. However, it may be that the effect of bird age and/or weight has a much greater effect on incidence of hock burn than litter quality, so "swamping" any effect that there might be, for flocks used in this study. It is of interest, in this respect, that a very significant strong positive association between mean flock HBS and BLI was found in this study. It is possible that BLI more closely reflects the biological load going through a house during a flock cycle, and so the total volume of faecal material deposited on the litter, than stocking density measured at one point in time. Increased faecal deposition would be likely to cause poorer litter quality and increased bacterial load. However, BLI is an artificial measure which does not take account of birds removed due to thinning.

Alternatively, the method by which producers predict stocking density, using standard growth curves, may account for the counter-intuitive negative association between flock mean HBS and several measures of stocking density. Producers aim for a target final stocking density, usually 38 kg per m^2 in the UK, using standard growth curves that predict average performance for the bird genotype used, to determine the stocking rate at which birds are placed and number of birds to be thinned prior to final slaughter. Birds which perform better than the average, and so have a greater final slaughter weight and possibly lower flock mortality, are likely to be birds least affected by disease. They might therefore be more mobile, spending more time walking between feeders and drinkers and so less time with hocks in contact with the litter, when hock lesions might develop.

Furthermore, where birds grow more slowly due to enteric disease, or increase their water consumption and excretion due to other types of disease, litter quality may deteriorate for periods during the flock cycle, giving both lower stocking densities, through slower growth and higher mortality, and higher incidence of hock burn. This hypothesis is supported by the finding of a fairly weak, very significant association between birds DoA and flock mean HBS and a weak, significant association between total percentage of carcases rejected and flock mean HBS. Such increases in DoA and carcase rejection rates may reflect diseased or injured birds which were immobile and so sat with hocks in contact with poor litter causing an increase in the prevalence of hock burn: a higher proportion of such diseased flocks are likely to die during transport or be rejected for human consumption. It is significant that stocking density does not appear in the univariate general linear model developed to account for variability of flock mean HBS, discussed below. Published studies also report inconsistent correlation of hock burn with stocking density: one study reported no correlation for flocks in Northern Ireland in 1994, but a significant correlation in 1993 (Menzies *et al.* 1998) while another found no significant correlation for the same flocks in 1986/7 (Bruce *et al.* 1990): a third study did find such an association (McIlroy *et al.* 1987).

As with many measures of stocking density, the lack of significant bivariate correlation between incidence of flock mean HBS and litter quality appears counter intuitive. However, for this study, litter quality was measured on one occasion only, immediately prior to slaughter, and it is possible that hock lesions are initiated earlier in the flock cycle so that litter quality measures taken late in the cycle do not consistently reflect prevalence of hock burn at slaughter. However, McIlroy *et al.* (1987) and Bruce *et al.* (1990) both found more hock and breast burn in flocks which had experienced an episode of 'acute litter deterioration', although during 1993 and 1994 no acute outbreaks of litter deterioration occurred for the same flocks. For these studies, the exact nature of these 'acute outbreaks', is not described in terms of litter quality, but it may be that, for flocks used in our study, no such 'outbreaks' occurred and so no significant correlation was found. However, a very significant effect of litter quality on hock burn prevalence was identified in our study in the general linear model developed for flock mean HBS.

From the differences in the aspects of flock husbandry for which significant bivariate correlations were identified for each condition, it is clear that the aetiology and pathogenesis of foot pad dermatitis and hock burn are not identical. However, because our study measured prevalence of these lesions only after slaughter, we do not know when in the flock cycle the lesions first appeared or which husbandry conditions determined whether or not lesions would develop. In order to identify the husbandry changes which might be made to reduce final incidence of foot pad dermatitis and hock burn, and when during the flock cycle they should be made, it would be necessary to carry out a longitudinal study, of the development and progression of each type of contact dermatitis lesion.

One of the aims of our study was to determine the extent to which contact dermatitis levels, recorded at the processing plant, reflect bird welfare on farm. In this respect, it is of interest that a significant positive bivariate correlation was found between bird gait score measured on farm and flock mean HBS. This is likely to be due to lame birds spending longer periods sitting with hocks in contact with the letter. No association between flock mean FPDS and gait score was found.

Clearly, the results of simple bivariate correlations may be misleading, as several factors which all appear to have an overwhelming effect may simply be co-varying as a group, and factors which have a small effect may be swamped by the effect of another which has a much larger effect. For this reason, univariate general linear models were developed, for foot pad dermatitis and hock burn, which eliminate these problems. Such models seek to account for the variations in the target variable due to changes in other measured variables, thus eliminating the effect of variables which co-vary. Clearly, there is likely to be some variation of the target variable which is due to factors not measured for any given study

In many respects the univariate general linear model developed to account for the variability in flock mean FPDS is explicable. The variation with season may be a result of poorer litter quality, due to ventilation rates being reduced in order to maintain house temperatures. Clearly, reduction in ventilation rate is likely to reduce the rate of removal of moisture and ammonia from the house, causing poorer litter. Other published studies have also reported a significant correlation between litter quality and prevalence of foot pad dermatitis (Ekstrand *et al.* 1997; Haslam 2006).

Feed supplier is likely to have an effect through feed quality, either because the consistency and constituents of the faeces are likely to affect the moisture content and pH of the litter, or through an effect on skin integrity, possibly due to micronutrient concentrations, reviewed by Mayne (2005). An effect of feed supplier on occurrence of foot pad dermatitis has also been identified by Ekstrand *et al.* (1998). However, in the current study, the effect of feed supplier might have been confounded by the effect of producer as each producer used specific feed companies. Ekstrand *et al.* (1997) also found that birds given nipple, rather than cup, drinkers and shallower litter depths were associated with less foot pad dermatitis: this was not found in the current study.

It is initially surprising that no measure of stocking density appeared in the model developed to account for the variation in flock mean FPDS, while a significant association was identified between flock mean FPDS and stocking rate from the bivariate correlations. This is likely to be because stocking rate was significantly correlated with litter quality (Spearman's rho 0.38, $P = 0.01$): thus these two variables co-varied and only one of these accounted for the variation of them both. The correlation of flock mean FPDS with litter quality was stronger than that with stocking rate, presented in Table 2: litter quality thus appeared in the model rather than stocking rate. However, no association was found between any measure of stocking density or stocking rate and incidence of foot pad dermatitis by Ekstrand *et al.* (1997), which was also reported by Martrenchar *et al.* (2002) and Dawkins *et al.* (2004): this in spite of the fact that several studies have identified associations between stocking density and litter quality (Martland 1985; Bruce *et al.* 1990; Tucker and Walker 1992; Gardbo Thomsen 1993), as found for all measures of stocking density in this study. It would seem that variables other than stocking density or stocking rate predominantly affect prevalence of foot pad dermatitis in broilers when measured close to slaughter.

The model developed to account for variability in flock mean HBS is also explicable. Factors which increase bird weight or age at slaughter, or which are related to reduced litter quality, tend to increase hock burn, whilst those which tend to reduce weight at slaughter, such as increasing percentage of wheat in feed or a greater proportion of small and emaciated birds, tended to reduce it. Indeed whole grain or cracked wheat may be incorporated into broiler diets for the purposes of slowing growth, as well as to stimulate the gizzard and to encourage a healthy gut micro flora, at inclusion rates varying from 0 to 30% of the total feed. The model also identified a very significant effect of genotype, with decreasing percentages of Genotype A birds in a flock, as opposed to Genotype B, causing an increase in flock mean HBS although the effect was small. This may be due to Genotype A birds having improved leg health, as found from data collected on farm (Knowles *et al.* In prep. 2006), also reported by Kestin *et al.* (1992; 1999), and so spending longer periods standing and walking, thus increasing contact time of feet with litter with the full weight of the bird forcing the pad on to the litter, which in turn implies they might have more foot pad dermatitis.

Surprisingly, no seasonal effect on hock burn was identified in this study. However, published studies also show an inconsistent association between hock burn and season. Bruce *et al.* (1990) also found no significant seasonal effect on hock burn in flocks in Northern Ireland in 1987/8, while McIlroy *et al.* (1987) had found such an association, for the same flocks, in 1984/5. Menzies *et al.* (1998) found a seasonal effect on contact dermatitis, in 1994, but no such correlation in 1993.

The inclusion of hatchery in the univariate model accounting for variation in hock burn levels may result from differences in the ages of parent flocks supplying different hatcheries, variation in chick quality or relative distance to each hatchery, although further research would be required to determine which aspects of the hatchery affect incidence of hock burn.

In conclusion, the current draft of the EU Broiler Directive proposes that incidence of foot pad dermatitis be monitored in birds going through processing plants, and that this incidence be used to determine the subsequent permitted stocking density of birds on the farm of origin. Our study has found that, using combined measures of severity and prevalence, foot pad dermatitis is more prevalent in UK flocks than hock burn. The prevalence of breast burn in UK flocks is very low. Several factors have been identified, from examination of bird husbandry conditions on the farm, which affect foot pad dermatitis and hock burn and which are different for the two conditions. The results of our study suggest that changes in some aspects of flock management, specifically measures which improve litter quality, may reduce the incidence of foot pad dermatitis and hock burn lesions. A strong seasonal effect on foot pad dermatitis was found which was additional to the effect of litter quality. Litter quality may be improved using ventilation and heating so as to maintain house temperatures and relative humidity, although it is not clear when during the flock cycle litter quality is critical. A change of feed supplier may reduce foot pad dermatitis and the use of Genotype B, rather than Genotype A birds will reduce foot pad dermatitis, although the effect is small.

Factors which might be manipulated to reduce hock burn at slaughter are those measures which improve litter quality, including increasing depth of litter at the end of the flock cycle, possibly by adding fresh litter, and taking measures to reduce bird weight at slaughter, including slaughtering at an earlier age, feeding meal rather than pelleted food, increasing the percentage of wheat in the diet and using Genotype A, rather than

Genotype B, birds. Further research would be required to determine what aspects of hatchery and transport of chicks to farms affect incidence of hock burn.

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	Moderate and severe foot pad dermatitis (%)	Moderate and severe hock burn (%)	Breast burn (%)
N	149	149	149
Mean	11.02	1.29	0.02
Median	0	0.002	0
Std. Error of Mean	0.002	0.085	0.001
Percentile 25	0.58	0	0
Percentile 75	2.93	0.77	0
Minimum	0	0	0
Maximum	71.51	33.33	1.56

TABLE 1. *Mean, median, standard error and 25 and 75 percentiles of moderate and severe foot pad dermatitis, hock burn and breast burn lesions for sub samples of 149 UK broiler flocks.*

Variable 1	Variable 2	Spearman's rho	Significance
Mean FPDS *	Mean HBS**	0.149	0.07
Mean FPDS	Litter quality close to slaughter	0.475	0.01
Mean FPDS	Stocking rate (birds/m^2)	0.229	0.05
Mean HBS	BLI***	0.294	0.01
Mean HBS	Stocking density using Mean *post mortem* weight at inspection	-0.299	0.05
Mean HBS	Stocking density using estimated weight at inspection	-0.204	0.05
Mean HBS	Stocking density using weight at slaughter	-0.357	0.01
Mean HBS	Stocking density using estimated weight at slaughter	-0.202	0.05
Mean HBS	Mean stocking density prior to thinning	-0.274	0.01
Mean HBS	Age at slaughter	0.484	0.01
Mean HBS	Live weight at slaughter	0.541	0.01
Mean HBS	Mean bird gait score	0.293	0.01
Mean HBS	Birds DoA	0.376	0.01
Mean HBS	Total percentage of birds rejected	0190	0.05

* Foot Pad Dermatitis Score
** Hock Burn Score
*** Stocking rate at placement, minus total flock mortality x Weight at kill

TABLE 2. *Significant bivariate correlations between plant measures of contact dermatitis and different measures of stocking density, bird weight and age, litter quality, mean gait score, DoAs and total carcasse reject data. All measures of stocking density are adjusted for mortality during the flock cycle.*

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Parameter Estimates

Dependent Variable: Mean FPDS

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	-0.806	0.231	-3.486	0.001	-1.262	-0.349
GENOTYPE A	0.003	0.001	1.831	0.069	0	0.005
SAMPLEDL	0.326	0.062	5.233	0	0.201	0.449
FEEDSUPPLY	0.385	0.123	3.127	0.002	0.141	0.628
HOCKSC	0.411	0.147	2.799	0.006	0.121	0.702
SEASONS	0.150	0.070	2.137	0.034	0.011	0.288
SEASONC	0.221	00.073	3.022	0.003	0.076	0.366

GENOTYPEA = percentage of birds which were Genotype A, rather than Genotype B
SAMPLEDL = mean litter score
FEEDSUPPLY = feed supplier
HOCKSC = flock mean hock burn score
SEASONS = sine cyclic term fitted with 12 month periodicity
SEASONC = cosine cyclic term fitted with 12 month periodicity

TABLE 3. *Parameter estimates for univariate model accounting for 36.6% of the variability in flock mean Foot Pad Dermatitis Score (FPDS).*

Parameter Estimates

Dependent Variable: HBS

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	-0.887	0.295	-3.002	0.004	-1.475	-0.299
GENOTYPEA	-0.003	0.001	-3.048	0.003	-0.005	-0.001
WHEATDT3	-0.022	0.011	-2.104	0.039	-0.044	-0.001
AGEATSLA	0.037	0.004	8.614	0.000	0.028	0.045
FOOTSCOR	0.090	0.041	2.184	0.032	0.008	0.171
FNLTDPTH	-0.015	0.008	-1.946	0.055	-0.030	0
RC6	-0.333	0.115	-2.901	0.005	-0.562	-0.105
SAMPLEDL	0.119	0.041	2.940	0.004	0.038	0.200
HATCHERY	Varies with hatchery	Varies with hatchery	2.318	0.004		

GENOTYPEA = percentage of Genotype A birds in flock
WHEATDT3 = percentage of whole or cracked wheat in diet 3
AGEATSLA = age at slaughter
FOOTSCOR = flock mean flock foot pad dermatitis score
FNLTDPTH = final litter depth
RC6 = percentage of small or emaciated birds
SAMPLEDL = mean litter score

TABLE 4. *Parameter estimates for univariate model accounting for 56.0% of the variability in flock mean Hock Burn Score (HBS).*

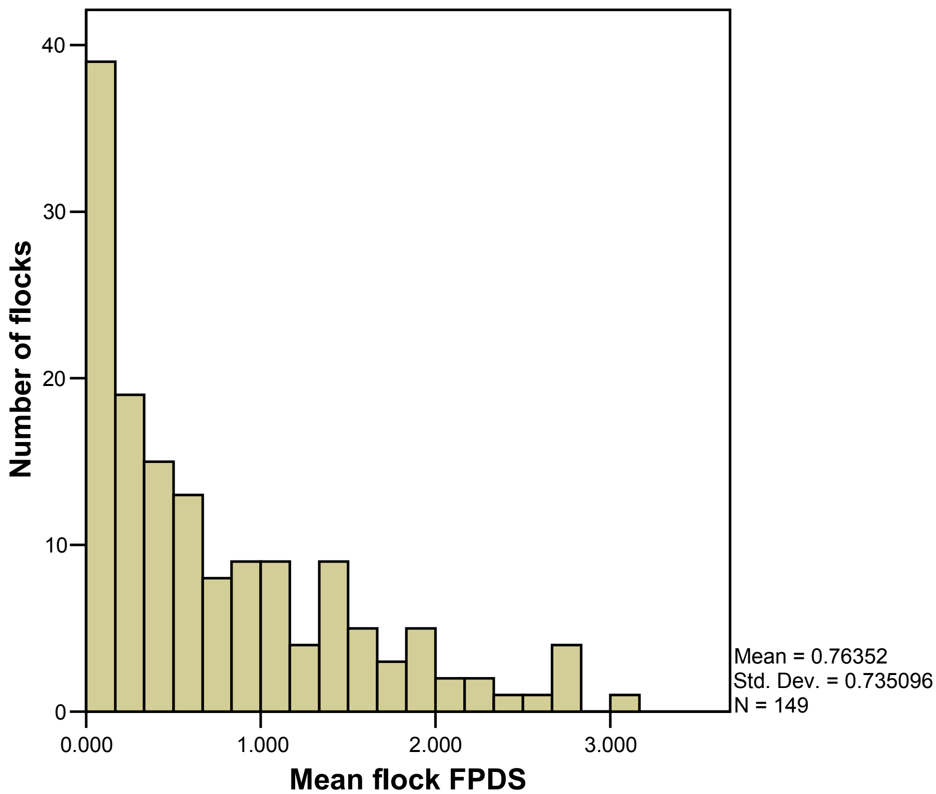

FIGURE 1. *Frequency distribution for mean flock Foot Pad Dermatitis Score (FPDS).*

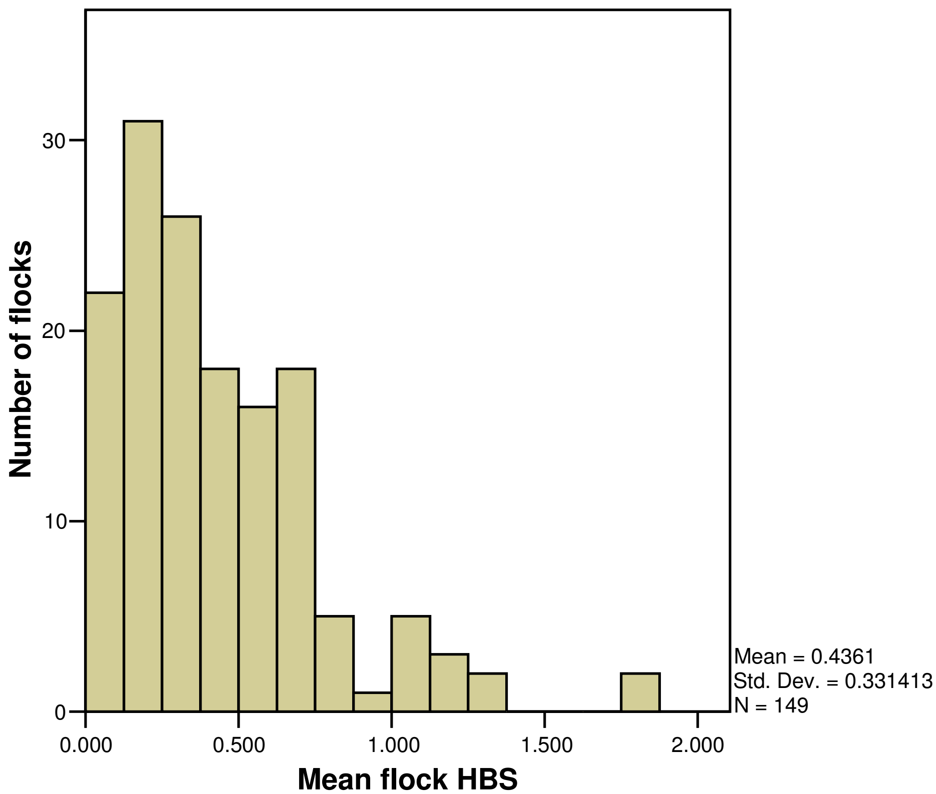

FIGURE 2. *Frequency distribution for mean flock Hock Burn Score (HBS).*

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