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Published in:
Animal

Link to article, DOI:
[10.1017/S1751731119001551](https://doi.org/10.1017/S1751731119001551)

Publication date:
2020

Document Version
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

Citation (APA):
Riber, A. B., Rangstrup-Christensen, L., Hansen, M. S., Hinrichsen, L. K., & Herskin, M. S. (2020). Characterisation of footpad lesions in organic and conventional broilers. *Animal*, 14(1), 119-128. <https://doi.org/10.1017/S1751731119001551>


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Characterisation of footpad lesions in organic and conventional broilers

A. B. Riber^{1†} , L. Rangstrup-Christensen¹, M. S. Hansen², L. K. Hinrichsen¹ and M. S. Herskin¹

¹Department of Animal Science, Aarhus University, DK-8830 Tjele, Denmark; ²National Veterinary Institute, Technical University of Denmark, Kemitorvet, DK-2800 Kgs. Lyngby, Denmark

(Received 20 February 2019; Accepted 6 June 2019; First published online 16 July 2019)

Recent data suggest that organic broilers often score worse on footpad lesions than conventional broilers but also that the current scoring of organic broiler feet may be misleading. In order to characterise footpad lesions in organic broilers, this study assessed and compared footpad lesions in a sample of 2987 conventional and 3578 organic broiler feet obtained from a large Danish abattoir during summer and winter. The feet were scored according to two scoring systems: the modified Danish surveillance scoring system and a histopathology-based new scoring system specifically developed to target the ability to differentiate between broiler feet with hyperkeratosis and ulcers. For both systems, all broiler feet with visible lesions were cross-sectionally incised. Significant differences between the two production systems were found for both scoring systems ($\chi^2 = 710$; $P < 0.001$ and $\chi^2 = 247$; $P < 0.001$ for the new and the surveillance systems, respectively), showing that a larger proportion of the organic feet compared to conventional feet – summer and winter – exhibited signs of hyperkeratosis. In addition, a smaller fraction of the organic feet than of the conventional feet were given the outermost scores, that is, normal or ulcerated; 13.4% v. 25.3% broiler feet were given score 0 for organic v. conventional production systems, respectively ($\chi^2 = 152$; $P < 0.001$), and 18.4% v. 23.8% feet were given score 4 for organic v. conventional production systems, respectively ($\chi^2 = 308$; $P < 0.001$). Thus, the results suggest that surveillance scoring systems such as the one used in Denmark are useful for the examination of footpad lesions in broilers from both types of production systems. However, the results have also raised attention to a typical characteristic of the feet of organic broilers, that is, profound hyperkeratosis, which may underlie potential misclassifications in surveillance scoring systems like the one used in Denmark. Among the possible solutions to this challenge to the correctness and fairness of the scoring system are improved procedures (such as mandatory incision), training of technicians and calibration of results (especially for the organic footpads).

Keywords: animal welfare, broilers, footpad dermatitis, histopathology, hyperkeratosis

Implications

Our results show that footpads from organic broilers differ from those of conventional broilers due to a larger proportion with hyperkeratosis and lower proportions of normal or ulcerated footpads. In contrast, data from the Danish surveillance programme suggest more severe footpad lesions in organic than conventional broilers. Others have reported that the current scoring of organic broiler feet may be misleading. Results from the present study suggest that correct scoring of footpad lesions in broilers – conventional or organic – by use of a simple scoring system is possible, but sufficient time for examination and training of technicians is needed.

Introduction

Footpad lesions are reported both in conventional and organic broilers at slaughter (Pagazaurtundua and Warriss, 2006a). The lesions cover different types of footpad dermatitis where contact-induced pathological changes may develop into hyperkeratosis (excessive growth and thickening of the keratin layer of epidermis (*stratum corneum*) (Arnould *et al.*, 2009)) or, in severe cases, to ulcers and necrosis (Greene *et al.*, 1985; Ekstrand *et al.*, 1998; Michel *et al.*, 2012). Seasonal relative humidity is one of the important risk factors for developing footpad lesions under indoor as well as outdoor conditions (Berg, 2004). Indeed, an effect of season on the prevalence of footpad lesions has been documented for both conventional and organic broilers in Denmark with the prevalence reaching extremes during summer (low) and winter (high) (Kvysgaard *et al.*, 2013).

[†] E-mail: anja.riber@anis.au.dk

The prevalence of footpad lesions in broilers is used worldwide as a welfare indicator, both for control of on-farm animal welfare and for research purposes. The EU Council Directive 2007/43/EC states that 'in the context of the controls performed under the Regulation (EC) No 854/2004, the official veterinarian shall evaluate the results of the post-mortem inspection to identify other possible indications of poor welfare conditions such as abnormal levels of contact dermatitis' (EC, 2007). In Denmark, this has been done systematically since 2002 by assessing a subsample of footpads from each flock of broilers slaughtered at Danish abattoirs (BEK, 2010). If certain threshold levels of footpad lesions are violated, producers are warned, requested to provide improvements to bedding or other insufficient conditions or receive cutbacks on the allowed stocking density of subsequent broiler flocks (BEK, 2010). Scientific evidence of the effects of this system does not exist, but the Danish poultry industry reports that it has resulted in significant improvements in footpad health of Danish broilers (Nygaard, 2016). The Danish surveillance scoring system is derived from the Swedish counterpart (Ekstrand *et al.*, 1998) and comprises a three-point scale in which scores 0, 1 and 2 designate no, minor and severe footpad lesions, respectively. A recent study based on the Danish surveillance scoring system has shown that organic broilers often score worse on footpad lesions than conventional broilers (Lund *et al.*, 2017).

Feet from conventional and organic broilers are typically assessed by the same scoring system despite the fact that they often appear differently in regard to colour, size and degree of hyperkeratosis (Lund *et al.*, 2017) and that genotypes, rearing environments, lifespan and activity level differ between organic and conventional broilers (Riber *et al.*, 2018). Recently, Lund *et al.* (2017) reported a low agreement between the assessment of organic broiler feet by the Danish surveillance scoring system performed at the abattoirs and consecutive assessments of the same feet done by trained researchers. Thus, their study provides evidence suggesting that the current scoring of organic broiler feet may be misleading. The scoring system used by Lund *et al.* (2017) was identical to the system used in the surveillance programme at Danish broiler abattoirs with the modification that an incision was made of all feet with a visible lesion. In contrast, the controllers using the Danish surveillance system during their meat inspections are told to make an incision when in doubt of the depth of the lesion. The Danish surveillance system is entirely based on macroscopic assessments and has not, to the knowledge of the authors, been cross-validated with histological examinations of the lesions – neither in conventional nor organic broilers.

The aim of the current study was to characterise macroscopically visible footpad lesions in organic broilers sampled during summer and winter. To do so, a new scoring system, focusing particularly on the ability to differentiate between hyperkeratosis and ulcerations, was developed using gross pathology and histopathology. Part of the characterisation involved comparison with conventional broiler feet. These were sampled in the same periods. For comparison, both

the new system and the modified Danish surveillance scoring system (i.e. including incision of all footpads with visible lesions) were used. Due to the differences in rearing environments, lifespan and activity level, we expected that organic broilers would have a higher occurrence of hyperkeratosis than conventional broilers and that this would become evident when using the new scoring system, specifically targeting the ability to differentiate between footpads with hyperkeratosis and ulcers.

Material and methods

All feet for the study were collected as a convenience sample from a large Danish abattoir, HKScan A/S (DK-7830 Vinderup, Denmark). At the abattoir, the feet were cut just below the hook joint. No information was provided on the sex of the birds or of the flocks from which the feet were collected. The conventional broilers were slaughtered at around 34 days of age and 2100 g, whereas the organic broilers were slaughtered around 56 to 68 days of age, depending on sex and growth, weighing 2100 to 2200 g (personal communication HKScan A/S, Vinderup, Denmark). The bedding material used indoor in both conventional and organic broiler production in Denmark is typically wood shavings, peat or straw pellets. The outdoor area in the organic broiler production is covered by low vegetation (grass) with varying degree of taller types of vegetation providing cover. The exception is the area closest to the chicken house, which typically consists of bare ground.

Development of a new scoring system to assess footpad lesions in broilers based on gross pathology and histopathology

In total, 602 broiler feet from five conventional and five organic flocks were collected in September and October 2016. Within each production system, around 50 feet were collected from two flocks on two farms and 100 feet were collected from one flock on a third farm. The method of sampling corresponded to the standard way of sampling for the Danish surveillance system; 50 feet were sampled from the first third of the flock and if a total of 100 feet were sampled, then the last 50 feet were collected from the last third of the flock. Within these limitations, the feet were sampled arbitrarily and always by taking only one foot per broiler – that is, each foot came from a unique bird. The conventional hybrid was Ross 308, whereas the organic feet originated from the hybrid CYJA57. The feet were kept refrigerated but not subjected to freezing.

Gross pathology and histopathology. All 602 feet were photographed, and a macroscopic description of footpad lesions was recorded. To compare the macroscopical and histological appearance of the footpad lesions, 28 organic feet and 28 conventional feet representing the macroscopic diversity, that is, feet with alterations ranging from not present to severe, were selected for histopathological examination at the National Veterinary Institute, Kgs. Lyngby, Denmark.

Table 1 Histopathological description (according to Michel *et al.*, 2012) of 56 broiler feet, the different types of lesions and their frequency

Type	Description	Number of feet	
		Conventional	Organic
Normal footpad	Normal skin structure with regular scales and normal thickness of epidermis	4	0
Type I (mild/early stage lesions)	Scales are prominent (secondary papillae). Mild-to-moderate hyperplasia and/or hyperkeratosis of the epidermis. Superficial congestion and oedema. Variable and mild inflammatory infiltration, that is, perivascularitis and subepithelial infiltration of mainly mononuclear cells or mixed infiltration (mononuclear cells and few granulocytes)	0	5
Type II (moderate/superficial lesions)	Marked hyperplasia and hyperkeratosis of the epidermis, abundant granulocytic (heterophils) infiltration in epidermis, pustules and prominent crusts, congestion in superficial dermis and inflammatory infiltration (perivascularitis and subepithelial infiltration) of mononuclear cells, mixed infiltration or granulocytes (heterophils)	1	10
Type III (severe/deep lesions)	Ulceration, that is, full-thickness necrosis of epidermis/loss of epidermis, replaced by a necrotic and suppurative material, underlying granulation tissue, type II lesions at the ulcer margins. Marked inflammatory infiltration (perivascularitis and subepithelial infiltration) of mainly granulocytes (heterophils), but also mononuclear cells or mixed infiltration	23	13

The feet were severed from the remaining part of the tarso-metatarsus proximal to digit I and then placed in 10% buffered formalin. Following fixation, the footpads were cut out and split in halves, embedded in paraffin wax, sectioned at 3 to 5 μm and stained with haematoxylin and eosin. The histological lesions were scored blinded according to Michel *et al.* (2012), as described in Table 1.

New scoring system. The outcomes of the gross and histopathological examinations of the lesions were combined in order to identify macroscopic features suitable for distinguishing lesions of hyperkeratosis from ulcerations (Table 1). The description in Table 1 of the different types of histologic footpad lesions was subsequently used to develop a new macroscopical scoring system focusing specifically on the ability to separate lesions of hyperkeratosis from ulcerations with loss of substance while including lesion size. This scoring system was divided into scores from 0 to 4. Score 0 included feet without lesions and feet with mild lesions (corresponding to histology type I lesions). Scores 1 and 2 included feet with hyperkeratosis (corresponding to histology type II lesions). Scores 3 and 4 included feet with ulcerations (corresponding to histology type III lesions). The scoring system, including descriptions and photos, is presented in Figure 1.

Characterisation of footpad lesions in organic and conventional broilers using the new scoring system and the modified Danish surveillance scoring system

For the characterisation of organic footpad lesions, conventional and organic broiler feet were collected during both summer and winter seasons. Feet were collected during one summer period (August to September, 2016) and involved 8 flocks of conventional broilers (8 producers)

and 15 flocks of organic broilers (6 producers). On national level, the monthly average precipitation during this period was 48 mm and the temperature was 16.2°C. Due to a European outbreak of avian flu, organic broilers had to be kept indoors during the following winter. Hence, sampling of feet from the winter period could not take place until January to February, 2018, which was a period of typical Danish winter weather with a monthly average precipitation of 54 mm and temperature of 1.6°C. The winter feet included 22 flocks of conventional broilers (20 producers) and 21 flocks of organic broilers (six producers). The abattoir personnel were asked to collect feet from 15 arbitrarily chosen flocks of organic broilers in each season. For each organic flock, feet from one flock of conventional broilers slaughtered during the same week should also be collected. However, a misunderstanding resulted in sampling of fewer conventional flocks during the summer period and a larger sample of flocks during the winter period. From each flock, the abattoir personnel was asked to collect 100 feet (range 88 to 100, median 100, mean 99.4) by randomly selecting 50 feet from the first third of the flock and 50 from the last third of the flock. In total, 6562 feet were included in this part of the study. The conventional hybrid was Ross 308, whereas the organic feet originated from two hybrids: JA757 and CYJA57 (the number of flocks per hybrid is unknown). The feet were frozen immediately upon slaughter.

Scoring systems used. The central footpads were assessed using the new scoring system (Figure 1) and the modified Danish surveillance scoring system (Figure 2). The modified version, that is, including an incision whenever there was a visible lesion on the central footpad, of the latter was chosen as this would standardise the methodology for the two observers involved in the study. Toepad lesions were

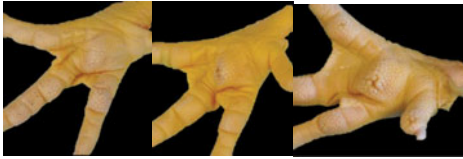
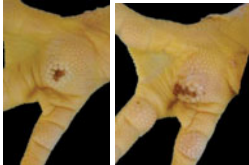

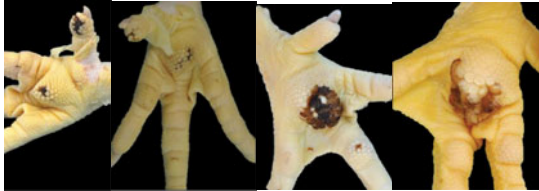
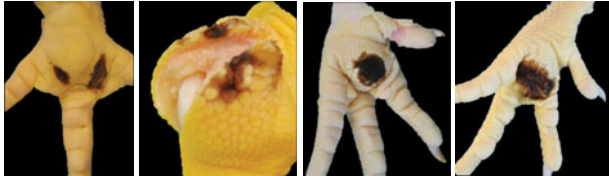
Score	Description	Photo examples
0 (No or mild lesions)	No lesion OR Mild brown discoloration of scales OR Mild erythema	
1 (Hyperkeratosis I)	Hypertrophic and hyperkeratotic scales with a yellow to brown discoloration ≤ 4 mm (measured at the widest point)	
2 (Hyperkeratosis II)	Hypertrophic and hyperkeratotic scales with a yellow to brown discoloration > 4 mm (measured at the widest point) OR Hypertrophic and hyperkeratotic scales with dark/black discoloration where, upon incision, the dermal layer of the foot pad is not exposed	
3 (Ulceration I)	Black discoloration between the scales OR Hypertrophic and hyperkeratotic scales with dark/black discoloration where, upon incision, the dermal layer of the foot pad is exposed covering an area of ≤ 4 mm ² OR Depressed lesion with loss of substance covering an area of ≤ 4 mm ²	
4 (Ulceration II)	Depressed lesion with loss of substance covering an area of > 4 mm ² OR Hypertrophic and hyperkeratotic scales with dark/black discoloration where, upon incision, the dermal layer of the foot pad is exposed covering an area of > 4 mm ²	

Figure 1 (colour online) Description and photographs of the new five-level macroscopical scoring system to evaluate footpad lesions in broilers. ©Photos: Lena Rangstrup-Christensen.

scored as absent, present (regardless of the number, size or severity, i.e. no incisions were made) or indeterminable (due to dirt or toes missing).

Procedure. Two observers from Aarhus University with extensive experience in using the Danish surveillance scoring system and educated in the new scoring system performed all assessments. When all feet were collected, the two observers spent 6 days within 1 month assessing all feet on a schedule balanced for season, production system, scoring system and observer. The observers were blinded to season and production system. However, the latter was often difficult

due to the distinct differences in appearance of feet from conventional and organic broilers. For each of the first 5 days of scoring, the last flock of the two production systems was assessed by both observers and by both scoring systems in order to be able to calculate interobserver reliability. On day 6, both observers assessed one flock from each of the two production systems twice, using each of the scoring systems in order to be able to estimate intraobserver reliability.

Approximately 20 h before assessment, all feet of the day were placed at 5°C for thawing. Assessment of all feet from one flock was completed before a new flock was started. All


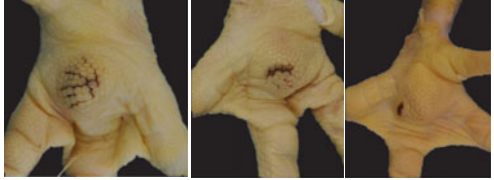

Score	Description	Photo examples
0 (No lesion)	No lesion OR Scar and no other lesion OR Mild discolouration $\leq 4 \text{ mm}^2$	
1 (Minor lesion)	Discolouration $> 4 \text{ mm}^2$ OR Superficial lesion with minimal to moderate epidermal necrosis OR Ulcer with epidermal necrosis through to dermis $\leq 4 \text{ mm}^2$ and no other lesions and discolouration	
2 (Severe lesion)	Ulcer with epidermal necrosis through to dermis $\leq 4 \text{ mm}^2$ in addition to other lesions and discolouration OR Ulcer with epidermal necrosis through to dermis $> 4 \text{ mm}^2$	

Figure 2 (colour online) Description and photographs of the three-level Danish surveillance system to evaluate footpad lesions in broilers.
©Photos: Lena Rangstrup-Christensen.

feet from a flock were placed individually in numbered trays (1 to 100) and assessed by using the scoring system specified by the balanced schedule for that particular flock. After completing all feet from a flock, the assessment was repeated, now using the other scoring system. Regardless of the scoring system used, whenever a visible lesion was present on the central footpad, a cross-sectional incision of the footpad was made with a disposable scalpel to allow examination for changes or bleeding in the dermal layer.

Statistical analyses

Statistical analyses were performed in R version 3.4.2 and all R-codes are provided as supplementary material (Supplementary Material S1). Chi-squared contingency table tests were applied to analyse for the overall effect of the production system (conventional *v.* organic) and for the effect of production system in each season (conventional *v.* organic during summer season; conventional *v.* organic during winter season) for each scoring system (new *v.* modified Danish surveillance scoring system). Proportion tests were applied to analyse whether the prevalence of different scores (within a scoring system) differed between production systems (overall and within each season).

Inter- and intraobserver data were analysed using the R packages IRR (Gamer *et al.*, 2012). Both unweighted and weighted Cohen's kappa coefficients were calculated. In the latter, the degree of disagreement between the two observers is weighted, that is, the higher the disagreement between the observers, the higher weight it is given. The flocks used for the inter- and intraobserver reliability tests were included in the analyses comparing the new and the modified Danish surveillance scoring system. For the flocks

assessed by both observers, only one of the assessments was included; the choice of which was based on a schedule balanced for production system and season. With regard to the flocks assessed twice by the same assessor, only the first assessment was included.

Results

An overview of the prevalence of the different scores when using the new and the modified Danish surveillance scoring system is shown in Tables 2 and 3, respectively. An overall difference between the two production systems was found both for the new ($\chi^2 = 710$, $df = 4$, $P < 0.001$) and for the modified Danish surveillance scoring system ($\chi^2 = 247$, $df = 2$, $P < 0.001$). When performing pairwise comparisons between production systems within scoring system and score, all turned out significant ($\chi^2 > 8$, $df = 1$, $P \leq 0.006$; Tables 2 and 3), except in the comparison of score 2 in the new scoring system where no difference was found between the two production systems ($\chi^2 = 1.4$, $df = 1$, $P = 0.24$; Table 2). In the new scoring system, fewer organic broilers were scored with the outermost values, that is, scores 0 and 4, compared to conventional broilers (Table 2). The percentage of organic compared to conventional broilers assessed as having a score 2, corresponding to the most profound prevalence of hyperkeratosis, was more than twice as high (Table 2). A similar pattern was found when using the modified Danish surveillance scoring system; fewer organic broilers were scored 0 and 2 but more with a score 1 (Table 3).

Also, when analysing separately for the two seasons, an overall difference between the two production systems was found when using the new scoring system (summer:

Table 2 Scoring of footpad lesions using a new scoring system, specially focusing on the ability to differentiate between hyperkeratosis and ulcerations in broiler feet in conventional and organic production systems

Score	Conventional ¹		Organic ²		Proportion tests ^{3,4}
	No.	%	No.	%	
0	756	25.3	478	13.4	$\chi^2 = 152, P < 0.001$
1	314	10.5	410	11.5	$\chi^2 = 1.4, P = 0.24$
2	341	11.4	1019	28.5	$\chi^2 = 287, P < 0.001$
3	444	14.9	1012	28.3	$\chi^2 = 169, P < 0.001$
4	1129	23.8	659	18.4	$\chi^2 = 308, P < 0.001$

¹ Originating from 30 flocks and 28 producers.

² Originating from 36 flocks and 12 producers.

³ Chi-square test for overall effect: $\chi^2 = 710, df = 4, P < 0.001$.

⁴ $df = 1$ in all proportion tests.

Table 3 Scoring of footpad lesions in broilers using the modified Danish surveillance scoring system

Score	Conventional ¹		Organic ²		Proportion tests ^{3,4}
	No.	%	No.	%	
0	777	26.0	498	13.9	$\chi^2 = 452, P < 0.001$
1	725	24.3	1426	39.9	$\chi^2 = 178, P < 0.001$
2	1482	49.7	1654	46.2	$\chi^2 = 8, P = 0.006$

¹ Originating from 30 flocks and 28 producers.

² Originating from 36 flocks and 12 producers.

³ Chi-square test for overall effect: $\chi^2 = 247, df = 2, P < 0.001$.

⁴ $df = 1$ in all proportion tests.

$\chi^2 = 205, df = 4, P < 0.001$; winter: $\chi^2 = 596, df = 4, P < 0.001$; Table 4) and the modified Danish surveillance scoring system (summer: $\chi^2 = 88, df = 2, P < 0.001$; winter: $\chi^2 = 202, df = 2, P < 0.001$; Table 5). A pattern similar to the one found in the analysis of the complete data set was found for the prevalence of the different scores; fewer organic broilers compared to conventional ones were assessed with scores 0 and 4 on the new scoring system and score 0 on the modified Danish surveillance scoring system. The only exceptions were that there was no difference between production systems on score 2 during the winter season in the modified Danish surveillance scoring system (Table 5), and that a difference between production systems was found in the prevalence of score 2 when using the new scoring system (Table 4).

An overview of the occurrence of toepad lesions (percentage of feet with a visible lesion on at least one toepad) in conventional and organic broilers in relation to the score of the central footpad is provided in Table 6. In total, 11.1% of the organic broilers and 28.1% of the conventional broilers had toepad lesions. Toepad lesions could not be determined on feet from 0.1% of conventional and 0.7% of organic broilers.

The interobserver reliability test for the two observers resulted in unweighted Cohen's Kappa values (κ), indicating moderate agreement (new scoring system: $\kappa = 0.49$; modified Danish surveillance scoring system: $\kappa = 0.56$), and in weighted Cohen's Kappa values (κ), indicating substantial

agreement (new scoring system: $\kappa = 0.68$; modified Danish surveillance scoring system: $\kappa = 0.65$).

The intraobserver reliability test for observer A resulted in unweighted Cohen's Kappa values (κ), indicating substantial agreement (new scoring system: $\kappa = 0.78$; modified Danish surveillance scoring system: $\kappa = 0.80$), and in weighted Cohen's Kappa values (κ), indicating almost perfect agreement (new scoring system: $\kappa = 0.88$; modified Danish surveillance scoring system: $\kappa = 0.83$). For observer B, the intraobserver reliability test resulted in unweighted Cohen's Kappa values (κ), indicating substantial agreement (new scoring system: $\kappa = 0.76$; modified Danish surveillance scoring system: $\kappa = 0.74$). For the weighted Cohen's Kappa values (κ), almost perfect agreement was achieved for the new scoring system ($\kappa = 0.84$), and substantial agreement was achieved for the modified Danish surveillance scoring system ($\kappa = 0.80$).

Discussion

In order to characterise footpad lesions in organic broilers, this study has compared a sample of 2987 conventional and 3578 organic broiler feet obtained from a large Danish abattoir and assessed footpad lesions according to two scoring systems: the modified Danish surveillance scoring system and a new scoring system, specifically targeting the ability to differentiate between footpads with hyperkeratosis and ulcers. For both systems, all feet with visible lesions were cross-sectionally incised. Differences between the two production systems were found for both scoring systems, suggesting that a larger proportion of the organic feet – collected during summer as well as winter – showed signs of hyperkeratosis, and a smaller fraction of the organic than the conventional feet were given the outermost scores, that is, normal or ulcerated. These results could be shown both when using the newly developed and the modified Danish surveillance scoring system.

Interestingly, toepad lesions were found at a nearly three times higher prevalence in conventional broilers than in organic broilers. As it is now, the controllers are instructed to focus on the central footpad during their assessments. With 9% of the toepad lesions in conventional broilers being present on feet with no lesions on the central footpad, it can be discussed whether equal emphasis should be placed on the condition of the toepads and the central footpads during the assessments. However, knowledge on the welfare consequences of toepad injuries is lacking. It is possible that toepad lesions imply less discomfort to a broiler than lesions on the central footpad as the weight load may be lower on the toepads compared to the central footpad, but for now, this remains speculative.

Overall, the available international studies on footpad lesions reflect considerable heterogeneity in the scoring systems used and in the level of how detailed they are described. Several of these published scoring systems focus only on the size of the footpad lesions (e.g. Pagazaurtundua and Warriss, 2006a and 2006b; Arnould *et al.*, 2009; Welfare Quality®, 2009) and include from few to many size categories. Other scoring systems combine lesion size and depth (Ekstrand *et al.*, 1998; Kjær *et al.*, 2006; Allain *et al.*,

Table 4 Scoring of footpad lesions, stratified according to summer and winter, using a new scoring system, specially focusing on the ability to differentiate between hyperkeratosis and ulcerations in broiler feet in conventional and organic production systems

Score	Summer					Winter				
	Conventional ¹		Organic ²		Proportion tests ^{5,6}	Conventional ³		Organic ⁴		Proportion tests ^{5,7}
	No.	%	No.	%		No.	%	No.	%	
0	236	30.0	290	19.6	$\chi^2 = 31, P < 0.001$	520	23.7	188	9.0	$\chi^2 = 167, P < 0.001$
1	74	9.4	251	16.9	$\chi^2 = 23, P < 0.001$	240	10.9	159	7.6	$\chi^2 = 14, P < 0.0002$
2	84	10.7	355	24.0	$\chi^2 = 57, P < 0.001$	257	11.7	664	31.7	$\chi^2 = 253, P < 0.001$
3	115	14.6	357	24.1	$\chi^2 = 28, P < 0.001$	329	15.0	655	31.2	$\chi^2 = 160, P < 0.001$
4	278	35.3	228	15.4	$\chi^2 = 116, P < 0.001$	851	38.7	431	20.6	$\chi^2 = 167, P < 0.001$

¹ Originating from eight flocks and eight producers.

² Originating from 15 flocks and 6 producers.

³ Originating from 22 flocks and 20 producers.

⁴ Originating from 21 flocks and 6 producers.

⁵ df = 1 in all proportion tests.

⁶ Chi-square test for overall effect: $\chi^2 = 205, df = 4, P < 0.001$.

⁷ Chi-square test for overall effect: $\chi^2 = 596, df = 4, P < 0.001$.

Table 5 Scoring of footpad lesions in broilers, stratified according to summer and winter, using the modified Danish surveillance scoring system

Score	Summer					Winter				
	Conventional ¹		Organic ²		Proportion tests ^{5,6}	Conventional ³		Organic ⁴		Proportion tests ^{5,7}
	No.	%	No.	%		No.	%	No.	%	
0	249	31.6	304	20.5	$\chi^2 = 34, P < 0.001$	528	24.0	194	9.3	$\chi^2 = 167, P < 0.001$
1	179	22.7	621	41.9	$\chi^2 = 82, P < 0.001$	546	24.9	805	38.4	$\chi^2 = 91, P < 0.001$
2	359	45.6	556	37.5	$\chi^2 = 14, P < 0.001$	1123	51.1	1098	52.4	$\chi^2 = 0.6, P = 0.4$

¹ Originating from eight flocks and eight producers.

² Originating from 15 flocks and 6 producers.

³ Originating from 22 flocks and 20 producers.

⁴ Originating from 21 flocks and 6 producers.

⁵ df = 1 in all proportion tests.

⁶ Chi-square test for overall effect: $\chi^2 = 88, df = 2, P < 0.001$.

⁷ Chi-square test for overall effect: $\chi^2 = 202, df = 2, P < 0.001$.

Table 6 Occurrence of toepad lesions in relation to the score of the central footpad assessed using the two different scoring systems. Broiler feet from conventional and organic production systems collected during summer and winter were included

Score of the central footpad	Conventional			Organic		
	No. feet of with toepad lesion	Total No. of feet	%	No. of feet with toepad lesion	Total No. of feet	%
New scoring system						
0	61	672	9.1	10	422	2.4
1	47	300	15.7	39	371	10.5
2	74	331	22.4	95	864	11
3	115	439	26.2	111	887	12.5
4	487	1048	46.5	93	608	15.3
Modified Danish surveillance scoring system						
0	64	692	9.3	13	444	2.9
1	135	701	19.3	145	1230	11.8
2	585	1397	41.9	190	1478	12.9

2009; Kaukonen *et al.*, 2016). The large number of scoring systems, of which many are not fully described, is a challenge – both scientifically and for the quality of surveillance systems. As described by Michel *et al.* (2012), at present, the countries in the European Union do not have one common system for scoring of footpad lesions in broilers despite the requirements laid out by the Council Directive 2007/43/EC to be able to ‘sample in a way that is scientifically based, objective and comparable’ (EC, 2007). As discussed recently by Winder *et al.* (2018) in systematic reviews of other aspects of farm animal science, such lack of common methodology (and/or reporting thereof) means that studies are not comparable and that confident decision-making is difficult.

Except for one older study by Greene *et al.* (1985), Michel *et al.* (2012) were among the first to establish a scoring system based on correspondence between the macroscopic appearance of the lesions and their histological features. However, common for all available scoring systems is that they

were not developed to include feet from organic broilers, and recent studies have suggested that lesions of organic broilers differ considerably from conventional feet (e.g. Lund *et al.*, 2017). Earlier studies comparing the occurrence of footpad lesions in broilers from different genetic lines – however not focusing specifically on hyperkeratosis – have also shown relatively large differences (Kjær *et al.*, 2006; Ask, 2010; De Jong *et al.*, 2012). Hence, in order to be able to characterise footpad lesions in organic broilers we developed a new scale, specifically targeting the ability to differentiate between hyperkeratosis and ulcerations, which has been suggested to be one area where footpad lesions of organic and conventional broilers differ (Lund *et al.*, 2017). The new scoring system presented in this study may be strengthened by further validation but is the first to provide a reliable link between macroscopic and microscopic features, and at the same time encompassing both conventional and organic broiler feet.

As the feet from organic and conventional broilers appear different, one challenge in the present study was the lack of opportunity of keeping the two observers blinded to the origin of the feet they were assessing. However, one of the observers was kept blinded to the hypothesis of the study (higher prevalence of hyperkeratosis in organic compared to conventional broiler feet) and the purpose of the new scoring protocol (increased ability to distinguish between hyperkeratosis and ulcers). The interobserver reliability test showed a moderate to substantial agreement between the two observers, indicating that skewing of assessments in the direction of the expected outcome did not occur. Studies involving comparison of visibly different treatments all share this challenge regarding blinding. In these cases, transparency about the possibilities for observers to be blinded as well as initiatives taken to limit or assess possible effects of the lack of blinding is important for readers to be able to evaluate potential influence on the results.

The purpose of our study was to characterise macroscopically visible footpad lesions in organic broilers for which reason a convenience sampling of the feet was considered acceptable. In contrast, a prevalence study would have required probability sampling of the feet. For this reason, we cannot based on our results conclude that in the Danish population of broilers, the organic broiler feet scored worse than the conventional ones as has been reported by Pagazaurtundua and Warriss (2006a) (in a scoring based on the size of the lesions), or that they scored better than the conventional ones as suggested by Gouveia *et al.* (2009) and Meluzzi *et al.* (2008). However, for the sample used in the present study, we can conclude that the feet from the organic broilers scored differently than those from conventional broilers, which relayed on a larger proportion of organic broiler feet with pronounced hyperkeratosis and a smaller fraction of the organic feet given the outermost scores, that is, normal or ulcerated. Recently, Lund *et al.* (2017) reported comparable differences between conventional and organic feet with regard to proportion of feet with hyperkeratosis and severe lesions, whereas the proportion of

normal feet was larger in organic broilers than in conventional broilers, contrasting our results.

In our study, where only two trained observers conducted the scoring, the use of the two scoring systems led to comparable results and to an acceptable level of agreement between and within observers. However, a recent study suggested that the footpad lesions of broilers are misclassified in the surveillance system used at Danish abattoirs and that this is the case especially for organic broiler feet (Lund *et al.*, 2017). In general, it is well known that clinical assessment may vary between and within observers (Thomsen and Baadsgaard, 2006), and low correlations between data obtained at meat inspection *v.* systematic observations have been shown also for other animal species (e.g. porcine lung pathology as examined by Nielsen *et al.* (2015)). In addition, studies have shown variation in scoring of broiler footpad lesions depending on abattoir (Pagazaurtundua and Warriss, 2006b; De Jong *et al.*, 2012). Such knowledge has led to increased focus on the need to calibrate measures within and between abattoirs, perhaps especially relevant for assessment of feet from organic broilers which typically only constitute a small proportion of the broilers produced every year. The observed lower interobserver reliability for organic *v.* conventional feet reported by Lund *et al.* (2017) may support this suggestion. Thus, in order to avoid bias in the scoring of footpad dermatitis in broilers – organic or conventional – there is a continuous need to focus on calibration and procedure optimisation.

As suggested by Lund *et al.* (2017), one possible initiative could be to simplify the scoring system. The current challenge of distinguishing between hyperkeratosis and ulceration in non-incised broiler feet bears some resemblance with the challenged ability to determine the depth of another type of environmentally induced injury in farm animals: the decubital shoulder lesions of sows (Herskin *et al.*, 2011; Rioja-Lang *et al.*, 2018) where ante-mortem determination of the severity of the lesions is difficult (Jensen, 2009). In that case, a new scoring system was developed focusing on one easy quantifiable measure of the lesions, their diameter (Jensen *et al.*, 2011), in order to have a useful tool. Such initiatives may facilitate the fairness experienced by farmers for whom the earlier, more complicated system had been difficult to use as instructed. In systems underlying authority control, fairness and especially the trust of fairness is central (Devitt *et al.*, 2016).

In scoring of footpad lesions in broilers, simple scoring systems based solely on the diameter of the lesions, without taking the depth and the possible loss of substance into consideration, already existed (e.g. Pagazaurtundua and Warriss, 2006a and 2006b; Arnould *et al.*, 2009; Welfare Quality®, 2009). These systems would probably be more repeatable than more complicated scoring systems, require less training, be faster and thus be more feasible as a high throughput solution. Automatic recording of the area of footpad lesions may even be a possibility, and a system capable of doing this is already in use at some broiler abattoirs. However, one might ask rhetorically whether systems only

based on size would be fair to the broilers from a welfare perspective. Despite only few studies relating footpad lesions to pain or other negative affective states, it is generally suggested that especially deeper, ulcerative injuries are linked to the experience of discomfort or pain for the birds as suggested by Michel *et al.* (2012). The fact that especially score 2 of the new scoring system, which represents superficial injuries, may often cover relatively large areas means that such a simplification of the scoring system would actually not increase validity of the scorings as a measure of the welfare of the birds. Before such a simple system can be considered valid in terms of broiler welfare, further studies are needed to examine the consequences of the lesions as such for the birds and to determine the degree of pain or other discomfort involved in the different categories of the lesions. Such knowledge would also be advantageous for the understanding of the welfare consequences of the lesions typical for the organic broilers, that is, lesions characterised by pronounced hyperkeratosis.

In this discussion, it is important to bear in mind that, in our study, the use of the two scoring systems led to comparable results and to acceptable levels of agreement between and within observers. Thus, it seems possible, even by use of the modified Danish surveillance scoring system, not to misclassify feet from organic broilers. However, one important aspect of this success may have been the opportunity to make a cross-sectional incision in the central footpad of all feet with visible lesions. In their recent study, Lund *et al.* (2017) compared scoring with *v.* without incision and came to the same conclusion. Hence, if the needed focus, time and training are available, it should be possible to score footpad lesions in broilers correctly – be it conventional or organic – by use of the modified Danish surveillance scoring system. However, the procedure of the present study, that is, to cut all feet with visible lesions, is time-consuming, and, at present, the guideline for controllers is only to cut when in doubt. If abattoir data are to be used for statistical documentation of animal welfare as a tool for the authorities in their control of on-farm welfare (BEK, 2010) or as basis for scientific studies (Kyvsgaard *et al.*, 2013), it is imperative that broiler feet from different production systems are either not scored using the same scoring system or that they are scored in a comparable and correct way.


Conclusions

In order to characterise footpad lesions in organic broilers, this study has assessed and compared footpad lesions in conventional and organic broilers according to two scoring systems: the modified Danish surveillance scoring system and a new scoring system specifically developed to target the ability to differentiate between feet with hyperkeratosis and ulcers. The results of the present study suggest that footpads from organic broilers scored differently compared to footpads from conventional broilers and that the differences mainly consisted of a larger proportion of organic footpads with pronounced hyperkeratosis. These results were evident

both when using the newly developed and the older scoring system used in the modified Danish surveillance programme during summer as well as winter. Thus, the results suggest that footpad lesions in broilers from both types of production systems can be assessed correctly by using the same scoring system. However, the results have also raised attention to a typical characteristic of the organic broilers, profound hyperkeratosis, which may underlie potential misclassifications in the surveillance system. Among the possible solutions to this challenge for the correctness and fairness of the scoring system are improved procedures (such as mandatory incision), training and calibration (especially for the organic footpads).

Acknowledgements

We thank HKScan, Vinderup, Denmark, for collecting broiler feet for the project, and Anton Steen Jensen, Lise Andreassen, Annie Ravn Pedersen and Helle Ruby for technical assistance. The research described in this paper has been commissioned by the Ministry of Environment and Food of Denmark as part of the 'Contract between Aarhus University and Ministry of Environment and Food for the provision of research-based policy advice at Aarhus University, 2017–2020'.

 A. B. Riber, 0000-0002-8644-3456

Declaration of interest

The authors declare no conflicts of interest.

Ethics statement

No project licence was required, as the materials used in the study were obtained at an abattoir. The study involved no live animals.

Software and data repository resources

None of the data were deposited in an official repository.

Supplementary material

To view supplementary material for this article, please visit <https://doi.org/10.1017/S1751731119001551>

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