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Keel-bone damage and foot injuries in commercial laying hens in Denmark

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Abstract

Keel-bone damage and foot injuries have a negative impact on welfare in laying hens. The extent of the problems in Danish commercial flocks of layers is unknown. Therefore, the aim of this study was to assess the current prevalence of keel-bone damage and foot injuries in Danish commercial flocks of laying hens and to investigate the effects of production system, housing system, hybrid and age. The occurrences of keel-bone damage, hyperkeratosis and missing toes were higher at 62 compared to 32 weeks of age, while the reverse was found for toe wounds, foot-pad lesions and bumble feet. There was no difference between barn and organic production systems in the risk of having keel-bone fractures and foot injuries, except that barn hens were more likely to have foot-pad lesions than organic hens (32 weeks: 16.1 vs 3.1%). Hens in multi-tiered systems were more likely to have keel-bone fractures compared to hens in single-tiered systems (62 weeks: 11.6 vs 4.9%). Of the four hybrids, Lohmann Brown Lite had a higher risk of keel-bone fractures, whereas bumble feet were found more frequently in Lohmann LSL. Keel-bone damage and foot injuries are less common in Danish non-cage systems compared to most of the reporting presently available from other countries. We suggest transnational studies, aimed at identifying the causal factors of this discrepancy, to increase existing knowledge on how to reduce incidences of keel-bone damage and foot injuries.

Keywords: *animal welfare, foot injuries, housing system, keel-bone damage, laying hen, production system*

Introduction

In recent years, attention has been directed to keel-bone damage in laying hens, and high incidences of keel-bone damage have been reported (Fleming *et al* 2004; Rodenburg *et al* 2008; Kappeli *et al* 2011; Wilkins *et al* 2011; Petrik *et al* 2015). Rodenburg *et al* (2008) reported that, in The Netherlands, 97% of the hens around 60 weeks of age housed in multi-tiered systems without outdoor access had keel-bone fractures, while the prevalence for similar-aged hens in single-tiered systems was 82%. The prevalence of keel-bone fractures seems to be unaffected by access to an outdoor area (Kappeli *et al* 2011) but increases with age of hens (Fleming *et al* 2004; Richards *et al* 2012; Petrik *et al* 2015). Poor animal welfare is linked to keel-bone fractures, as fractures may result in acute and chronic pain in addition to reduced mobility (Nasr *et al* 2012a,b, 2013). Thus, a hen experiencing a keel-bone fracture early in the production period may suffer from poor welfare during a substantial part of her lifespan.

The keel bone is prone to damage due to its anatomical position (Fleming *et al* 2004; Kappeli *et al* 2011). Similarly, the feet are exposed to injuries due to continuous contact with litter or housing equipment, such as perches and a wire floor (Tauson & Abrahamsson 1994; Wang *et al* 1998; Pickel *et al* 2011). Wang *et al* (1998) found that the risk of foot-pad lesions in laying hens is affected by the condition of the litter; the occurrences of foot-pad lesions were 92 and 38% on wet and dry litter, respectively. Producers consistently report that it can be more difficult to control the humidity in layer houses with outdoor access, especially in periods with wet or humid weather conditions. Thus, outdoor access may be a contributing risk factor for foot-pad lesions.

An investigation of keel-bone damage and foot injuries has not been previously performed in commercial flocks of layers in Denmark. The aim of this study was to assess the current prevalence of keel-bone damage and foot injuries in commercial laying hens in Denmark and to investigate the effects of production system (barn vs organic), housing system (single vs multi-tiered), hybrid (four different strains) and age (32 vs 62 weeks of age).

Materials and methods

A study of the prevalence of keel-bone damage (ie deviations and fractures) and foot injuries (defined as hyperkeratosis, toe wounds, missing toes, foot-pad lesions and bumble feet) was performed from January 2013 to October 2014 on 31 commercial farms. Production system (barn or organic), housing system (single or multi-tiered) and hybrids included in the study are presented in Table 1. Perches were available in all farms visited, and multi-tiered systems consisted of three tier levels. In the barn system flock sizes ranged between 2,000 and 14,000 (mean: 7,002; median: 6,000), whereas the organic flocks all consisted of 3,000 hens, apart

Table 1 Number of flocks according to type of production system, housing system and hybrid.

Hen breed	Barn		Organic		Total
	Single-tiered	Multi-tiered	Single-tiered	Multi-tiered	
Hisex White	0	0	1	3	**4**
ISA Brown	1	4	0	0	**5**
Lohmann Brown Lite	1	2	6	1	**10**
Lohmann LSL	1	4	7	0	**12**
Total	**3**	**10**	**14**	**4**	**31**

from two flocks with 4,500 and 2,200 hens, respectively. In contrast to the organic flocks, none of the barn flocks had outdoor access. Each farm was visited twice; at around 32 weeks of age (30–40 weeks; median 32) and around 62 weeks of age (58–66 weeks; median 62). At both visits, 100 individuals were caught from different areas in the house and trained observers assessed the keel bone and feet using the scoring protocol developed by participants from eight European countries in the Core Organic project Healthy Hens (CORE organic HealthyHens project 2014). Presence of both fractures (fresh and old) and deviations of keel bones were assessed by palpation. The severity of the keel-bone deviation was registered according to the protocol, but in the analysis only presence or absence was used. The thumb and index fingers were placed on each side of the keel bone and slid slowly downwards feeling for callus material and malformations (fractures) or deviations. The palpation for deviations was supported by a visual inspection. The feet were examined for presence of hyperkeratosis, toe wounds and missing toes. Lastly, the condition of the foot-pads was scored on a four-point scale: normal; small lesion (< 0.2 cm); larger lesion (> 0.2 cm); or bumble foot (dorsal swelling), but in the analysis of the data on presence of lesions, small and larger lesions were pooled. Prior to the data collection, two of the observers participated in a training programme arranged by the HealthyHens project focusing on assessing welfare of organic layers (Gunnarsson 2012), where they were trained and tested in the assessment protocol. For keel-bone deviations, the two observers were tested for inter-observer reliability until a good agreement was achieved; a Kappa of 0.82 was found, corresponding to almost perfect agreement. Inter-observer reliability for keel-bone fractures was only tested for the entire group of observers participating in the workshop and a prevalence-adjusted bias-adjusted Kappa (PABAK) of ≥ 0.4 was found, corresponding to a moderate agreement (for more details, see Hinrichsen [2015]). In addition, for a different study, the two observers assessed keel-bone damage using the same method as described for the present study in 13 flocks between February and December 2013 (Hinrichsen unpublished data). From each flock, 4 to 21 hens (mean 16.9; total 220) were selected for a post mortem dissection performed by a poultry veterinarian. Only 5.9% of the hens were assessed differently in the post mortem dissection compared to the on-farm palpation, reaching an agreement between the palpation and the dissection methods of 86% (Spearman's rank correlation coefficient test, r^2 = 0.8587; $P < 0.001$). This is similar to the accuracy found by other researchers (eg Wilkins *et al* 2004, 2011; Petrik *et al* 2013; Casey-Trott *et al* 2015). The two observers trained a third observer, and this team of three observers formed into teams of two and conducted all the assessments performed during the on-farm visits. Prior to the data collection for the present study the two experienced observers had assessed keel-bone damage in approximately 1,000 birds, whereas the third observer had assessed 100 birds and was assisted by one of the more experienced observers.

A sample size of 100 individuals was calculated as sufficient to provide an estimate of the true proportions of the parameters investigated. We expected that the highest frequencies of any of the welfare indicators chosen would be found for the keel-bone damage. Based on a pilot study, we estimated that the true proportion of hens having either keel-bone deviations or fractures would be 10%. We then used the following equation to calculate the required sample size: $n = (Z^2 \times P[1 - P])/e^2$, where Z is a value from the standard normal distribution corresponding to the desired confidence level (1.96, when at a confidence level of 95%), P is the expected true proportion and e is the desired precision, which is half of the desired confidence interval width. With a confidence level of 95%, an expected true proportion of 10%, and a confidence interval of 12%, the required sample size was 96 individuals.

The effects of production system, housing system, hybrid, age and some of the interactions between them on the keel-bone damage and foot injuries were analysed using a logistic regression model with a random effect of flock. Stepwise reduction of the model was conducted and non-significant interactions were removed from the model. The study was, however, not designed to investigate all the interactions. Thus, the four-way interaction, all the three-way interactions (except the one between age, housing system and production system) and the two-way interactions between hybrid and housing/production systems were not analysed due to insufficient replications. The foot-pad condition was analysed in two separate logistic regression models; one for foot-pad lesions and one for bumble foot.

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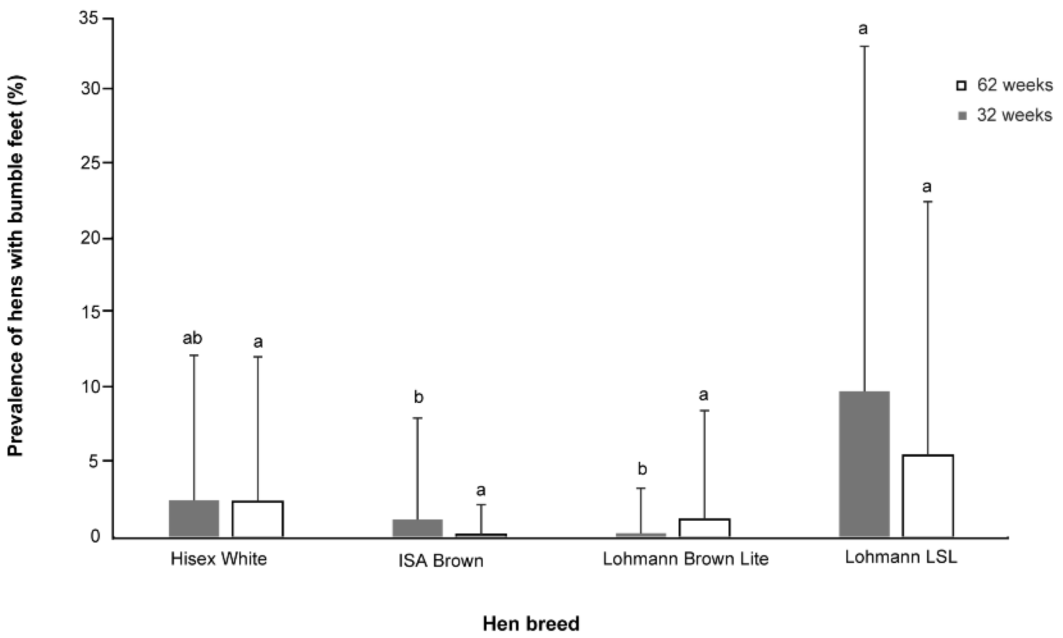
Table 2 Prevalence (%) and range (in brackets) of keel-bone damage (fractures and deviations) at 32 and 62 weeks of age in the two housing systems (single or multi-tiered) and the two production systems (organic or barn).

	32 weeks				62 weeks			
	Single-tiered		Multi-tiered		Single-tiered		Multi-tiered	
	Organic	Barn	Organic	Barn	Organic	Barn	Organic	Barn
Keel-bone fractures	2.9 (0–15)		4.7 (0–13)		4.9 (0–13)		11.6 (3–31)	
Keel-bone deviations	4.3 (0–13)	0.7 (0–2)	1.8 (0–5)	3.3 (0–7)	8.7 (3–23)	6.3 (1–12)	13.6 (8–29)	13.3 (2–21)

Table 3 Prevalence (%) and range (in brackets) of foot injuries at 32 and 62 weeks of age in the two production systems (organic or barn).

	32 weeks		62 weeks	
	Organic	Barn	Organic	Barn
Hyperkeratosis	1.3 (0–8)		3.5 (0–89)	
Toe wounds	1.6 (0–9)		0.5 (0–8)	
Missing toes	1.9 (0–8)		2.8 (0–10)	
Foot-pad lesions	3.1 (0–24)	16.1 (0–45)	4.8 (0–38)	4.4 (0–13)
Bumble feet	4.8 (0–33)		3.0 (0–30)	

Figure 1



Prevalence of hens (%) with bumble feet at 32 and 62 weeks of age specified for the four hybrids. Standard deviations are provided, and significances between hybrids, within age, are indicated by different superscripts.

All statistical analyses were conducted in R version 3.1.3 using the R-packages lme4, car and multcomp (Hothorn *et al* 2008; Fox & Weisberg 2011; Bates *et al* 2014; R Development Core Team 2014). In addition, results on keel-bone damage are presented using the newly proposed Simplified Keel Assessment Protocol (SKAP) system (Casey-Trott *et al* 2015).

Results

The incidences of keel-bone damage and foot injuries are provided in Tables 2 and 3 and Figure 1. Neither barn nor organic production system affected the likelihood of having keel-bone fractures or foot injuries, with the exception of an increased prevalence of foot-pad lesions among hens in barn production systems compared to organic production

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systems at 32 weeks of age (χ^2 = 73.4, df = 1; P < 0.001). The only other interaction found to be significant was the three-way interaction between production system, housing system and age in the analysis of keel-bone deviations (χ^2 = 6.64, df = 1; P = 0.01). In the organic flocks, a higher prevalence of keel-bone deviations was found in single- compared to multi-tiered systems at 32 weeks of age; the reverse was found at 62 weeks of age in the organic flocks and at both 32 and 62 weeks of age in the barn flocks. Higher incidences of keel-bone deviations were found at 62 compared to 32 weeks of age, irrespective of housing or production system. Categorising the occurrences of keel-bone damage at 62 weeks of age, according to the SKAP system, resulted in 3.8% of all the examined hens having both keel-bone deviations and fractures, 4.1% only had fractures, 6.8% only had deviations, whereas 85.3% had neither fractures nor deviations.

The laying hens were more likely to have keel-bone fractures (χ^2 = 50.7, df = 1; P < 0.001) and hyperkeratosis (χ^2 = 41.0, df = 1; P < 0.001) in addition to be missing a toe (χ^2 = 5.6, df = 1; P = 0.02) at 62 compared to 32 weeks of age. In contrast, toe wounds (χ^2 = 16.5) and foot-pad lesions (χ^2 = 39.6) were less common at 62 compared to 32 weeks of age (df = 1; P < 0.001). There was no difference between the two housing systems in the likelihood of having overall foot injuries (χ^2 < 0.36, df = 1; P > 0.5). However, hens in multi-tiered systems were more likely to have keel-bone fractures (OR = 4.25, χ^2 = 7.3, df = 1; P = 0.007). The hybrid Lohmann Brown Lite had a higher prevalence of keel-bone fractures (5.2 and 8.9% at 32 and 62 weeks, respectively) compared to the three other hybrids (Lohmann LSL: 3.3 and 7.8%; Hisex 3.0 and 6.6%; ISA Brown 2.2 and 7.4% at 32 and 62 weeks, respectively, χ^2 = 10.4, df = 3; P = 0.02). The occurrences of hyperkeratosis, toe wounds, missing toes and foot-pad lesions were not affected by the hybrid (χ^2 < 4.0, df = 3; P > 0.26), whereas the prevalence of bumble feet differed between hybrids at 32 but not at 62 weeks of age (χ^2 = 12.6, df = 3; P = 0.006; Figure 1).

The mortality in the barn flocks at 62 weeks of age ranged between 2.5–10.1%, except for one flock suffering from erysipelas which had a mortality of 31.6% (all barn flocks: mean 9.4%; median 5.8). In the organic flocks, the mortality at 62 weeks of age ranged between 2.8–6.8% (mean 3.7%; median 3.4).

Discussion

Examination of keel-bone damage and foot injuries revealed a difference between the two ages. The occurrences of keel-bone damage, hyperkeratosis and missing toes were greater in older hens, which for keel-bone damage corresponds to previous findings (Fleming *et al* 2004; Richards *et al* 2012; Petrik *et al* 2015; Hinrichsen *et al* 2016). Therefore, these types of damages seem to accumulate over time. The hens had more toe wounds, foot-pad lesions and bumble feet at 32 compared to 62 weeks of age, thus suggesting that the skin of the feet hardens with increasing age. The prevalence of foot-pad lesions was similar to reporting from The Netherlands (Bestman & Wagenaar 2012), but lower than seen in Austria (Niebuhr *et al* 2009).

The prevalence of keel-bone fractures at 32 weeks of age was lower than previously reported for laying hens in non-cage systems at a similar age in other countries (24–36%; Richards *et al* 2012; Petrik *et al* 2015). The prevalence of keel-bone fractures at 62 weeks of age was notably lower than previously reported from other countries (> 48%; Wilkins *et al* 2004; Rodenburg *et al* 2008; Kappeli *et al* 2011; Wilkins *et al* 2011; Richards *et al* 2012; Petrik *et al* 2015). Due to the level of experience of the observers, their training in the palpation method together with members of seven other research groups in Europe working on keel-bone damage and the high agreement between the results found by palpation and dissection, we have full confidence in the accuracy of our results. Low frequencies of keel-bone damage were also found in a pilot project at Copenhagen University, Denmark, where a total of 309 laying hens of varying ages (range or mean not specified) from 14 flocks (barn, organic, free-range and cage systems) were dissected, and only one hen was found with keel-bone deviation, whereas none were diagnosed with fractures (Kabell 2014). The present study did not aim at determining the causal factors of keel-bone damage. However, we suspect that the Danish management practice of supplying laying hens with a particulate calcium source (limestone or oyster shell) in addition to the powdered calcium in the feed has a reducing effect on the prevalence of keel-bone damage observed in Denmark. The slower dissolution in the gastrointestinal tract of particulate forms compared to powdered forms of calcium may minimise the need for mobilisation of bone calcium reserves during the night, where the calcification of eggshells takes place and no feed intake occurs (Scott *et al* 1971; Roland & Harms 1973; Farmer *et al* 1986). Particulate limestone has been reported to increase the amount of bone material in the keel bone compared to a diet with powdered limestone (Fleming *et al* 1998). Fleming *et al* (2004) concluded that the underlying cause of keel-bone damage is lack of bone mass. If the level of calcium in the gastrointestinal tract is low, the hens will mobilise calcium from the bones, resulting in lower bone strength and mass. Thus, the additional calcium source, ie particulate limestone or oyster shell, provided in Danish egg production may contribute to a stronger keel bone that resists damage.

The risk of having keel-bone fractures and deviations was increased in multi-tiered compared to single-tiered systems, with the exception of the prevalence found in organic systems at 32 weeks of age, where the opposite pattern was found possibly due to very low occurrences of keel-bone damage. This corresponds with previous findings stating that the prevalence of keel-bone damage was higher in multi-tiered compared to floor systems (Kappeli *et al* 2011), and that the severity and prevalence of keel-bone damage increase as the complexity of the equipment in the house increases (Wilkins *et al* 2011). Scholz *et al* (2014) reported more unsafe landings on steel perches. Presently, in Denmark, steel is the perch material normally used in multi-tiered systems, whereas wooden perches are more common in single-tiered systems, suggesting that the material used in the multi-tiered systems may pose a higher risk of keel-bone damage.

In the present study, the hybrids differed in terms of the likelihood of having bumble feet and keel-bone fractures. Previous studies have reported differences between hybrids in the prevalence of bumble feet (Tauson *et al* 1994; Abrahamsson *et al* 1996), while others have not found any differences between hybrids (Tauson *et al* 1999). Abrahamsson *et al* (1996) found that Lohmann LSL hens were more likely to have bumble feet than ISA Brown when housed in aviaries, corresponding to our findings. The cause of the increased risk of bumble feet in Lohmann LSL hens is unknown. Apart from bumble feet, foot injuries and keel-bone damage have not previously been found to be associated with hybrid (Tauson *et al* 1999; Kappeli *et al* 2011).

An increased prevalence of foot-pad lesions among hens in the barn compared to the organic production system was observed, which was the opposite of our prediction. Wang *et al* (1998) found that the litter condition was a risk factor for foot-pad lesions, with increased prevalence of foot-pad lesions when the litter was wet. In the present study, the litter quality was not measured, but the higher stocking density in the barn production system may have decreased the litter quality compared to the organic production system. Thus, the higher stocking density in the barn production system may have outweighed the possible contributing effect of outdoor access on moisture in the litter in the organic production systems, resulting in the observed increased prevalence of foot-pad lesions in the barn production system.

Animal welfare implications and conclusion

It has been documented that laying hens with keel-bone fractures experience pain (Nasr *et al* 2012a). Foot injuries are also likely to be painful to the laying hen; it is known from turkeys and broilers that foot-pad dermatitis is associated with discomfort and pain (Bessei 2006; Hocking & Wu 2013). The present study shows that occurrences of keel-bone damage and foot injuries are low among hens in Danish non-cage systems compared to most reporting from other countries. However, there is still a need for improvement, particularly since the risk of keel-bone damage was increased in the multi-tiered system and this housing system is becoming more popular among producers in Denmark. We suggest transnational studies, aimed at identifying the causal factors of this discrepancy in prevalence between countries, to increase existing knowledge on how to reduce incidences of keel-bone damage and foot injuries.

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