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RESEARCH ARTICLE

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Rearing, bird type and pre-slaughter transport conditions of broilers II. Effect on foot-pad dermatitis and carcass quality

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Abstract

A multivariable linear model was used to analyse the incidence of carcass quality defects over one year in a commercial database that included 1,856 flocks of Ross broilers (9,188 shipments, 1,975,420 carcasses inspected). The incidence of foot-pad dermatitis (FPD), scratches and wing and back haematomas was scored and analysed in terms of the effects of transport distance, arrival time to the slaughterhouse, waiting time at the slaughterhouse, maximum outside temperature on the day of transport, feed conversion rate, stocking density, bird type (yellow-skinned females or males, white-skinned females or males and roaster females), thinning (birds transported after thinning, birds remaining after thinning, and non-thinned flocks), bed litter type (rice hulls, chopped straw or wood shavings), and ventilation system (dynamic, static or tunnel). The incidence of FPD was significantly (p<0.001) lower at higher maximum temperatures and higher in flocks with a higher feed conversion rate. FPD also increased with stocking density (kg/m^2) and was, on average, 5.0% higher in males than females. Regarding thinning, FPD was 13% lower in birds transported after thinning. Birds raised on chopped straw had more FPD (49.3%), followed by wood shavings (31.1%). Scratches were higher at higher temperatures and increased with transport distance. Birds transported after thinning had 5.8% more scratches than non-thinned birds, while increased stocking density (kg/m^2) on the farm tended to increase scratches. Back haematomas were 32.6% higher in birds that were thinned, while wing haematomas increased with stocking density (kg/m^2). Back haematomas were also 23.7% higher in males and more common in white-skinned birds.

Additional keywords: poultry; thinning; slaughterhouse; mortality; welfare.

Abbreviations used: CV (coefficient of variation); FCR (feed conversion rate); FPD (foot-pad dermatitis); NT (non-thinned flocks); R-F (roaster females); SD (standard deviation); T1 (birds transported after thinning); T2 (birds remaining after thinning); WHT-F (white-skinned females); WHT-M (white-skinned males); YEL-F (yellow-skinned females); YEL-M (yellow-skinned males).

Authors' contributions: Conceived and designed the study: MAI, JM, CdB. Acquired and interpreted the data: IF, MN, PMG. Analyzed the data: MAI, PMG, CdB. Drafted the manuscript: MV, MAI, CdB.

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Introduction

It has been known for decades that rearing conditions, as well as pre-slaughter handling and transport, can affect the carcass quality of broilers (Knowles & Broom, 1990; Mitchell & Kettlewell, 1994; Bedanova *et al.*, 2007; Oba *et al.*, 2009). The effect of transport distance, stocking density, bedding and ventilation have been considered in terms of their effects on some carcass defects, such as foot-pad dermatitis (FPD) (*e.g.*, Martrenchar *et al.*, 2002; Baracho *et al.*, 2006; Hunter *et al.*, 2017) but less is known about the possible effects of bird type (sex, weight and skin colour), or thinning, where a first group of birds is removed from the main flock and taken to slaughter a number of days before the last group. The paucity of information about those effects is partly due to the lack of large sets of informative commercial data that permit valid statistical comparisons.

Many authors have found a direct negative relationship between FPD and animal welfare (*e.g.*, Nijdam *et al.*, 2004; Broom & Reefman, 2005), while in economic terms, scratches and haematomas cause important economic losses for the poultry industry (Bilgili *et al.*, 2009), but have been studied less. Dermatitis in broiler chickens mostly affects the foot-pad and the skin of the tibio-tarsal joint (Greene *et al.*, 1985). FPD is a problem for broiler health and welfare since lesions may become infected and cause pain (Ekstrand *et al.*, 1998), but the implications may vary depending on the overall effects on the bird (*e.g.*, how the lesions affect gait or recumbency; Martrenchar *et al.*, 2002). Several large scale studies have been performed to assess the incidence of FPD in different countries. For example, more than 20 years ago, Ekstrand *et al.* (1997) found 32% mild and 6% severe FPD in 101 flocks in Sweden, while more recently, De Jong *et al.* (2012) reported 25% mild and 38% severe FPD in 386 flocks in Holland. Although broiler production has evolved substantially over the years, it seems quite clear that high litter moisture helps to increase problems (Shepherd & Fairchild, 2010). As stated by Baracho *et al.* (2006), more studies are needed to identify the most appropriate litter material to help decrease FPD, but Taira *et al.* (2014) clearly showed that using litter that accumulates less moisture reduces FPD incidence.

Relatively little is known about the causes of scratches and haematomas on broiler carcasses. Scratches are known to increase with stocking density (Elfadil *et al.*, 1996) but the few large scale studies published in this area report widely varying percentages (80% of the study population had scratches in Allain *et al.*, 2009; 22% in Gouveia *et al.*, 2009; 73% in Pilecco *et al.*,2012). With such a wide variation it is difficult to suggest a specific cause. A similar variability occurs with haematomas, however, their incidence is lower than FPD in general, ranging from negligible (Folegatti *et al.*, 2006) to 80% (Allain *et al.*, 2009). In this study we aimed to assess whether rearing conditions on the farm, such as bird type and thinning procedures, and pre-slaughter conditions during and after transport affected the incidence of FPD, scratches and haematomas on the carcasses of broiler chickens using a large commercial data base containing records over a one-year period.

Material and methods

Animals and carcass quality measurements

We used a dataset provided by one of the main broiler producers in Spain (COREN SCG) from January 2015 to February 2016, including 213 farms that produced six flocks per year. Production was intensive with a mean slaughter weight of 2.8 kg at 42 d, rearing sexes separately. Fasting, loading and transport conditions were similar among flocks and are described in Villarroel *et al.* (2018). The birds were Ross commercial breed and were of five types; yellow-skinned females (YEL-F) and males (YEL-M), white-skinned females (WHT-F) and males (WHT-M), and roaster females (R-F). The total number of shipments for each type of bird and the distribution of shipments in terms of bird type, thinning and transport conditions were summarized in Villarroel *et al.* (2018). In addition, the differences in distribution of type of bedding material and the ventilation system among bird types are shown in Table 1.

The incidence of the main carcass quality problems (FPD, scratches and wing and back haematomas) was obtained on a sample of 215 birds from each shipment from the farm to the slaughterhouse. All carcass quality problems were assessed visually by slaughterhouse personnel on the line and consisted of reporting presence or absence. A bird was defined as having FPD if a black callous or dot was seen on the bottom of the foot (severity was not measured). A bird was defined as having a scratch or haematoma if either defect was 1.5 cm long/large or longer/larger. The type of diet and feeding system were the same among farms.

Table 1. Average distribution (%) of shipments with respect to type of bedding material and the ventilation system for the different bird types (YEL-F = yellow-skinned females, YEL-M = yellow-skinned males, WHT-F = white-skinned females, WHT-M = white-skinned males, R-F = roaster females).

	YEL-F	YEL-M	WHT-F	WHT-M	R-F
Bedding material					
Rice hulls	52.1	60.7	58.1	65.9	63.5
Chopped straw	11.9	8.9	11.4	11.6	9.0
Wood shavings	36.0	30.4	30.5	22.5	27.5
Ventilation system					
Dynamic	39.7	34.8	37.9	33.2	66.6
Static	43.9	20.4	47.9	6.5	3.6
Tunnel	16.4	44.8	14.2	60.3	29.8

Data processing and statistical methods

The original file contained 2,342 flocks and 11,560 shipments to the slaughterhouse. After data cleansing (defined in Villarroel *et al.*, 2018), the definitive dataset analysed contained 35,518,924 birds from 1,856 flocks and 9,188 shipments. The incidence of the carcass quality problems studied at the slaughterhouse was analysed using the multivariable linear model of the GLM program of SAS (version 9, 2002). The experimental unit was the shipment. The independent variables included both categorical (bird type, thinning, type of bedding material and ventilation system), and continuous variables (maximum outside temperature on the day of transport, distance travelled, average live weight, stocking density, arrival time and waiting time prior to unload). In the case of the effect of bird type, the analysis included the use of factorial contrasts between bird sex and skin colour, plus a contrast between roaster females versus the other females (yellow and white skinned). The feed conversion rate (FCR) of the birds (kg fed divided by kg gained) was also taken into account at the flock level as a continuous variable. The influence of the interval of days between the first thinning and final shipment was analysed. The effects of the continuous variables were analysed using polynomial orthogonal contrasts. Interactions among all variables were considered in the model. The mean values, ranges, standard deviations and coefficients of variation of all the continuous variables are shown in Table 2.

For the analysis of variance we used the type I and type III sums of squares. We verified the assumption of normality and homogeneity of variance of the variables analyzed using the residues of the model via the graph of normality and the graph of residues versus the predicted values, respectively. We did not observe any anomaly that could invalidate the assumptions for the analysis. The least square means (marginal means) for each categorical variable were corrected by using the BYLEVEL option in SAS to calculate the average values associated with the mean commercial production conditions within each specific category for the data base. This procedure is justified by the fact that, as mentioned in Villarroel *et al.* (2018) and as shown additionally in Table 1 for type of bedding material and the ventilation system, the independent variables studied were not uniformly distributed among the different types of birds.

Results

In Table 3 we show the estimated regression coefficients of the continuous variables that had a significant influence on FPD, scratches and haematomas. The average bird weight per shipment did not have a significant effect on the carcass quality traits studied within each bird type, which might be related to the low variability among shipments for a given bird category (Table 4).

Table 2. Description of the variables used in the analysis (n=9 188 shipments) of carcass defects in chickens.

Traits	Average	SD[2]	Min	Max	CV%[3]
Shipment size (number of birds)	3,852	1,100	1,001	6,336	28.6
Dependent variables (%)					
Foot-pad dermatitis	35.5	27.3	0	100	76.88
Scratches	21.8	8.53	0	76.3	39.1
Back haematoma	12.1	5.23	0	40.5	43.2
Wing haematoma	12.4	3.10	0	30.7	25.0
Independent variables					
Distance from farm to slaughterhouse (km)	55.4	20.6	8.0	119	37.4
Arrival time to slaughterhouse (min) [1]	594	199	53.0	1,184	33.6
Waiting time at slaughterhouse (min)	177	93.2	15	681	52.7
Average bird weight (kg)	2.80	0.490	1.41	3.96	17.
Maximum outside temperature (ºC)	22.1	7.52	7.6	40.1	34.1
Interval first thinning and final shipment (d)	5.26	4.02	0	10	76.4
Feed conversion rate	1.73	0.067	1.48	2.31	3.83
Stocking density (animals/m^2)	11.8	2.17	6.07	18.9	18.4
Stocking density (kg/m^2)	32.2	4.6	20.0	43.9	14.2

[1] minute 0 was 20:00 the night before slaughter. [2] SD = standard deviation. [3] CV% = coefficient of variation expressed in percentage.

Table 3. Significant effect of the continuous variables studied regarding incidence of carcass quality problems in chickens.

Factor	Coefficient	SE [2]	*p* [3]
Food pad dermatitis			
Maximum temperature (ºC)	-3.15	0.237	<0.001
Maximum temperature (ºC) [1]	0.0394	0.00507	<0.001
Feed conversion rate	59.6	4.91	<0.001
Stocking density (kg/m^2)	2.123	0.829	<0.001
Stocking density (kg/m^2) [1]	-0.0255	0.0129	0.0486
Scratches			
Maximum temperature (ºC)	0.698	0.0747	<0.001
Maximum temperature (ºC) [1]	-0.0108	0.00159	<0.001
Distance (km)	0.0315	0.00468	<0.001
Stocking density (kg/m^2)	0.195	0.0267	<0.001
Back haematomas			
Arrival time (min)	0.00178	0.000387	<0.001
Stocking density (kg/m^2)	-0.861	0.156	<0.001
Stocking density (kg/m^2) [1]	0.0138	0.00243	<0.001
Wing haematomas			
Arrival time (min)	0.00119	0.00021	<0.001
Stocking density (kg/m^2)	-0.178	0.085	<0.001
Stocking density (kg/m^2) [1]	0.00444	0.00132	<0.001

[1] quadratic effect. [2] SE: standard error. [3] *p*: level of significance

Foot-pad dermatitis

The maximum outside temperature on the day of transport had a significant quadratic influence on the incidence of FPD. In the range studied, FPD decreased as the maximum outside temperature increased, so that, as shown in Fig. 1, FPD decreased from around 57% in January-February to 10% in August-September. The FCR during the rearing period had a significant effect on FPD, which increased by 5.96 percentage units per each 0.1 increase in FCR. Moreover, stocking density (kg/m^2) had a significant influence on FPD, with generally more defects at higher densities, as shown in Fig. 2. There was an increment of 11.8 percentage units from the lowest to the highest stocking density for FPD.

Skin colour had a significant effect on FPD (Table 5). White skinned birds showed a lower incidence of FPD than the yellow-skinned birds (30.0% in white-skinned, 43.4% in yellow-skinned). Regarding bird sex, females had a lower incidence of FPD (35.8 *vs*. 37.6% in males). When comparing T1 and T2, FPD was higher in T2 birds (Table 6). The aggregate of thinned birds (T1+T2) compared to NT showed that FPD was higher in NT (31.6 thinned *vs*. 36.3% NT). Bedding material had a significant ($p<0.001$) effect on FPD, with the highest incidence in chopped straw (49.3 ± 1.57%), followed by rice hulls (33.7% ± 1.29%) and wood shavings (31.1 ± 1.36%). Ventilation type did not have an effect on carcass quality traits.

Scratches

In Table 3 we show the estimated regression coefficients of the continuous variables that had a significant influence on scratches. The maximum outside temperature on the day of transport had a significant quadratic influence on the incidence of scratches. Scratches, as opposed to FPD, increased with maximum outside temperature, up to a maximum value at 31ºC, increasing from around 16% in January to 24% in August-September. Other factors related to transport such as the distance from the farm to the slaughterhouse, had a significant effect on scratches, which increased by 1.58 per each increase in 50 km transport distance. Higher stocking densities (kg/m^2) tended to increase scratches linearly (Fig. 2). There was an increment of 4.7 percentage units from the lowest to the highest stocking density for scratches.

There was a significant interaction between bird type and sex for scratches, as there was a greater difference between males and females in white-skinned than in yellow-skinned birds. In terms of thinning effects, scratches were lower in T2 birds (Table 6). The aggregate of thinned birds (T1+T2) compared to NT

Table 4. Summary of the variability in body weight among shipments within bird types and thinning categories.

Bird type [1]	Thinning [2]	Number of shipments	Average body weight (kg)	SD	CV%
YEL-F	T1	72	1.84	0.211	11.5
	T2	255	2.51	0.127	5.06
	NT	1,270	2.46	0.152	6.18
YEL-M	T1	161	2.84	0.158	5.57
	T2	368	3.37	0.197	5.85
	NT	98	3.06	0.230	7.53
WHT-F	T1	18	1.66	0.146	8.79
	T2	48	2.59	0.162	6.27
	NT	594	2.52	0.191	7.59
WHT-M	T1	743	2.56	0.139	5.43
	T2	2,810	3.25	0.192	5.90
	NT	402	3.16	0.228	7.22
R-F	T1	362	1.61	0.088	5.43
	T2	1,010	2.51	0.157	6.24
	NT	38	2.40	0.394	16.4

[1] See Table 1 for abbreviations. [2] T1 = birds transported after thinning, T2 = birds remaining after thinning, NT = non-thinned flocks.

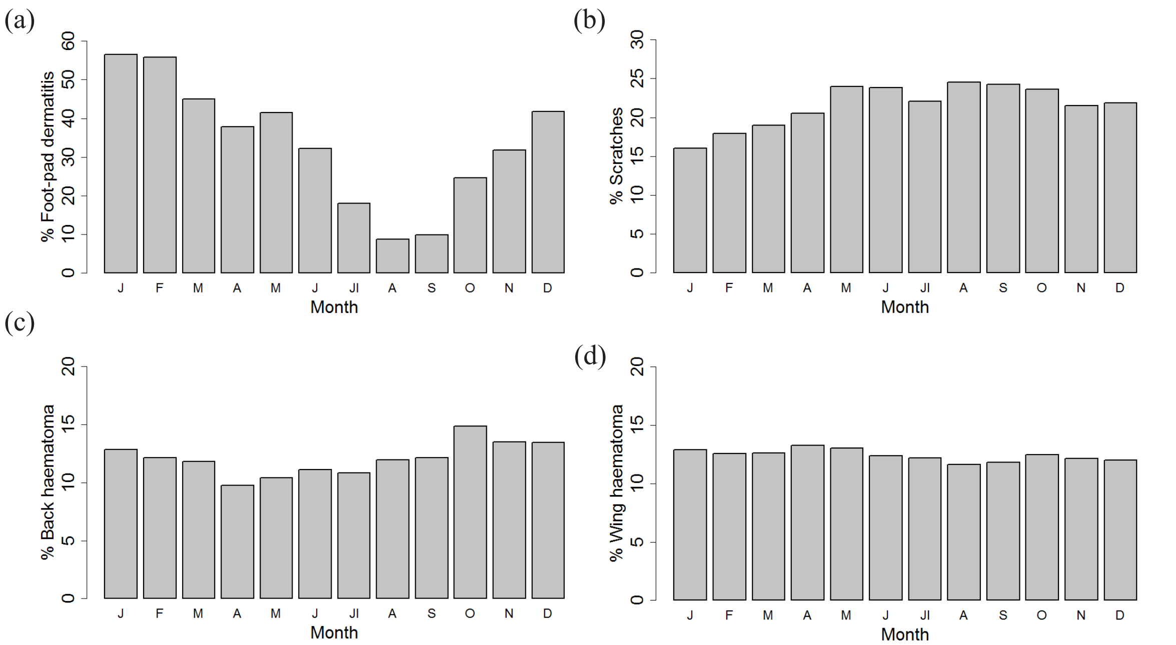

Figure 1. Influence of maximum outside temperature (averaged per month of the year) on (a) foot-pad dermatitis, (b) scratches, (c) back haematoma and (d) wing haematoma in all categories of broilers combined.

showed a decrease in the incidence of scratches (23.5 thinned *vs*. 22.2% NT). We found no significant effects of bedding material or ventilation on scratches.

Haematomas

In Table 3 we show the estimated regression coefficients of the continuous variables that had a significant influence on haematomas in the statistical analysis. The maximum outside temperature on the day of transport did not have a significant quadratic influence on the incidence of haematomas. Outside temperature had little effect on haematomas (see Fig. 1). Arrival time had a significant effect on back and wing haematomas, increasing 0.106 and 0.07 percentage units, respectively, per each one hour increment in arrival time. In the case of back haematomas their incidence was minimized at a stocking density of 31.2 kg/m^2, but the decrease only

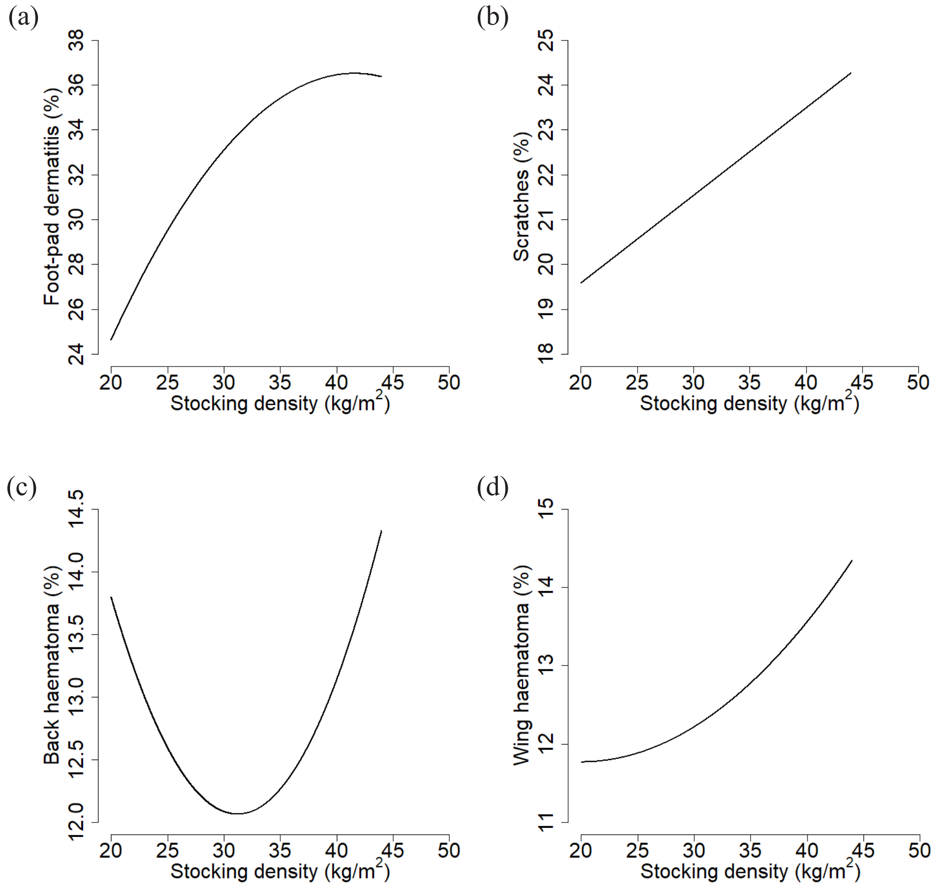

Figure 2. Influence of stocking density on the incidence of (a) foot-pad dermatitis, (b) scratches, (c) back haematomas and (d) and wing haematomas in broiler chickens.

Table 5. Description of the carcass defects in terms of bird type and levels of significance.

Dependent variables (%)	Bird type [1]					*p*			
	YEL-F	YEL-M	WHT-F	WHT-M	R-F	Y *vs.* W[2]	M *vs.* F[3]	Int[4]	R-F *vs.* F[5]
Foot-pad dermatitis	42.4	44.4	29.2	30.8	31.3	<0.001	0.0324	0.813	<0.001
Scratches	20.8	22.6	20.1	23.0	20.2	0.421	<0.001	<0.001	0.540
Back haematoma	8.7	10.1	10.7	13.8	12.8	<0.001	<0.001	<0.001	<0.001
Wing haematoma	10.6	12.5	11.9	13.2	12.6	<0.001	<0.001	<0.001	<0.001

[1] See Table 1 for abbreviations. [2] Contrast yellow-skinned *vs* white skinned. [3] Contrast male *vs* female broilers. [4] Interaction between skin colour and sex. [5] Contrast roaster females *vs* the other females (yellow and white skinned)

Table 6. Description of the carcass defects in chickens in terms of thinning with the levels of significance.

Dependent variables (%)	Thinned[1]			*p*	
	T1	T2	NT	(T1+T2) *vs.* NT	T1 *vs.* T2
Foot-pad dermatitis	28.7	34.5	36.3	<0.001	<0.001
Scratches	26.9	20.1	22.2	<0.001	<0.001
Back haematomas	13.1	13.0	9.8	<0.001	0.492
Wing haematomas	10.5	13.6	11.4	0.071	<0.001

[1] T1 = birds transported after thinning, T2 = birds remaining after thinning, NT = non-thinned flocks.

represented 2 percentage points with respect to the extreme values of the range of stocking density. Higher stocking densities (kg/m^2) tended to increase wing haematomas (Fig. 2), but the increase was only of 2.5 percentage units from the lowest to the highest stocking density.

White-skinned birds showed a higher incidence of back and wing haematomas (12.2% in white-skinned *vs*. 9.4% in yellow-skinned for back haematomas; and 12.5% in white-skinned *vs*. 11.5% in yellow-skinned for wing haematomas). Regarding bird sex, females had a lower incidence of back haematomas (9.7 *vs*. 12.0% in males) and wing haematomas (11.2 *vs*. 12.8% in males). There was a significant interaction between bird type and sex for haematomas, as there was a greater difference between males and females in white-skinned than in yellow-skinned birds. However, for wing haematomas the difference between males and females was higher in yellow-skinned birds. When comparing T1 and T2, wing haematomas were higher in T2 birds (Table 6). The aggregate of thinned birds (T1+T2) compared to NT showed a decrease in back haematomas (13.0 thinned to 9.8% NT). For wing haematomas, a significant interaction between bird type and thinning was also observed (Fig. 3), as the effects of thinning were more evident in male than in female broilers. We found no significant effects of bedding material or ventilation on haematomas.

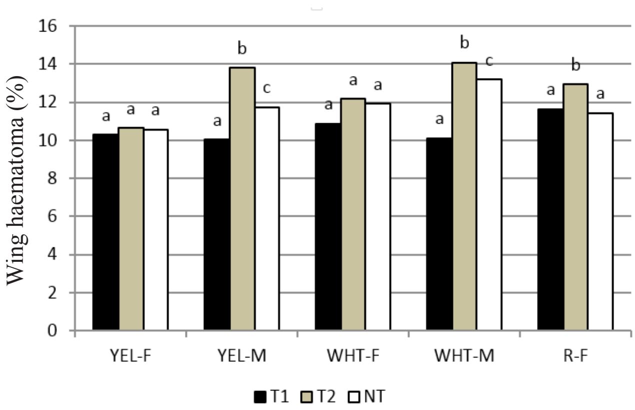

Figure 3. Interaction between bird type and thinning on the incidence of wing haematomas. Means within the same bird type with different letters were significantly different ($p<0.05$).

Discussion

Observational studies with a large number of data, such as the current one, have the advantage of being directly applicable to commercial practice and provide consistent conclusions. However, the discussion of the results of studies lacking an experimental design is not simple since some of the effects can be difficult to separate. For instance, the specific effects of thinning are confounded with bird type and weight, since, as shown in the results section, some bird types were hardly ever thinned (*e.g.*, R-F) and T1 birds are substantially lighter than T2 or NT birds. In order to consider those effects and bird weight, bird skin colour and sex, it was necessary to have a large sample size (215 birds controlled per each of 9188 shipments or a total of 1,975,420 birds inspected) and use appropriate statistical models.

Food pad dermatitis

The incidence of FPD found in our study (35.5% of all shipments) is similar to the 38% reported by Ekstrand *et al.* (1997) but considerably lower than the 64% found by De Jong *et al.* (2012). The maximum outside temperature had an important effect on FPD, which was considerably lower in the summer months, as also reported by Shepherd & Fairchild (2010) and De Jong *et al.* (2012). We found a six fold higher incidence of FPD in January as compared to August, presumably related to relative humidity, which affects litter humidity. High relative humidity on the farms in the winter does not allow the litter to dry out, so more ammonia accumulates and causes dermatitis (De Jong *et al.*, 2012). The physical properties of air dictate that relative humidity (which we did not measure directly), is higher at lower temperatures, but that may be aggravated in chicken farms if ventilation is reduced when it gets colder, irrespective of the ventilation system (Feddes *et al.*, 2002; Saraiva *et al.*, 2016). However, it was common commercial practise in the farms studied to replace wet bedding material with new dry litter (for the same flock), which might help to lower rates of FPD. Martrenchar *et al.* (2002), who collected data on the extent of litter renewal on turkey farms, noted that an indicator for higher FPD was a higher frequency of litter replacement. Those authors conclude that litter humidity can be the result of a poor FCR (reduced absorption of nutrients), which, in turn, can be the result of poor handling conditions, health problems or an unbalanced diet. Taking into account that, in the current study, all the flocks were on the same feeding program, we suggest that sub-optimal rearing systems were associated with a higher FCR and a higher FPD.

The density expressed as kg/m^2 was also considered since it is used in welfare legislation in the European Union. Its effect was more important on FPD than the other carcass lesions, which agrees with Hall (2001) who compared similar densities to the ones used in the current study, but does not agree with other larger epidemiological studies such as Allain *et al.* (2009) who found no relation between stocking density and FPD, although in a narrower range of densities (95% of flocks were kept at 36.0-38.8 kg/m^2).

With respect to bird type, we found that yellow-skinned birds (both males and females) had 13.4 percentage units more FPD than white-skinned. Few other studies have considered the effect of bird skin colour on FPD. Regarding bird sex, FPD was slightly (5%) higher in broiler males than females which might be related to their heavier slaughter weight (3.12 kg in males and 2.46 kg in females). Several authors have noted that FPD tends to be higher in older and/or heavier birds (*e.g.*, Pagazaurtundua & Warriss, 2006; Kaukonen *et al.*, 2016).

T1 had a lower overall incidence of FPD than T2 or NT, which coincides with De Jong *et al.* (2012) and Kaukonen *et al.* (2016), who reported less FPD in birds in the first shipment (lighter), than those not thinned. Few other studies have considered the effect of thinning on FPD or carcass defects.

Regarding bedding material, birds on chopped straw had a 17% higher occurrence of FPD than when rice hulls or wood shavings were used, which agrees with results from Hunter *et al.* (2017) who report 40.6% FPD using wheat straw and a lower incidence (6.4%) with pine shavings. Depending on the particle size, chopped straw can become compact and retain water, also making it more difficult for chickens to peck and turn over the litter, and straw is also more abrasive than other litter types (the particle size of straw in the current study was 3 to 5 cm). In alternative systems (in traditional free range and extensive indoor using a mixture of straw and wood shavings), poorly insulated houses and inefficient ventilation and heating can lead to a sharp increase in the incidence of FPD to around 80% (Gouveia *et al.*, 2009). As a result, it is important for farmers to pay special attention to managing litter quantity and type during winter months.

Scratches

The incidence of scratches found in our study (21.8% of all shipments) is similar to Gouveia *et al.*, 2009 (22%) but much lower than Allain *et al.* (2009) (80%) and Pilecco *et al.* (2012) (73%). In the current study there were more scratches at higher maximum outside temperatures. Travel distance also tended to increase scratches, which suggests that the latter occur mostly during pre-slaughter transport. Since Estevez *et al.* (2002) found low levels of aggression in domestic fowl, the increased scratches during transport are probably not due to fighting but simply the result of birds trying to move around each other in a cramped space.

Regarding bird type, we found no effect of skin colour on the incidence of scratches but there was an effect of bird sex since male birds had 11.7% higher incidence of scratches than females. With respect to thinning, T2 had a significantly lower incidence of scratches in most bird types, probably since there were fewer birds/m^2 than either T1 or NT birds. As suggested by Saraiva *et al.* (2016), thinning provides the remaining birds with more space, possibly reducing scratches. Moreover, we also observed fewer scratches in non-thinned than in T1 birds, which might be related to less stress caused by handling. In order to help explain the difference in estimated means of the scratches among bird categories and thinning categories, a multiple regression analysis was carried out. For that we used the fifteen mean values estimated using the BYLEVEL option for each combination of bird type and thinning categories. The regression equation obtained was: -40.0 (±19.6, SE) + 9.88 (±3.40)*average body weight (kg) + 2.92 (±0.904)*animal density (number of birds reared/m^2) with the following levels of probability: p=0.013 for weight and p=0.007 for density. Thus, bird categories or thinning associated with both a higher bird weight and more birds reared/m^2, had more scratches. Along those lines, Elfadil *et al.* (1996) found a direct relationship between the incidence of abdominal scratches and stocking density at 35 and 42 d of age, which they explain in part due to the differences in the degree of feathering. In addition, Allain *et al.* (2009) found a positive relationship between scratches and stocking density and an inverse relationship between FPD and scratches, which may imply a link between the two since FPD birds may be less willing to move around or interact with neighbours. The current research also indicates a negative correlation between these lesions (-0.12, p<0.001).

Haematomas

The incidence of haematomas found in our study (around 12% of all shipments for both back and wing) is higher than that reported by Folegatti *et al.* (2006) (negligible bruises) and Allain *et al.* (2009) (2.8% bruises on the back, 3.1% on ventral surface). Arrival time had a significant effect on haematomas. An earlier arrival time (in minutes after 20:00 on the day before slaughter) implied fewer haematomas possibly since handling was mostly at night and birds were less excitable. As seen in Villarroel *et al.* (2018), earlier arrival times were also associated with less dead on arrival (DoA). The influence of stocking densities on haematomas was less than for the other carcass defects. As in scratches, using a multiple regression analysis to explain the difference in estimated means (n=15) of the haematomas among bird and thinning types, we only found a significant effect (p=0.0124) of average bird weight (within each combination of bird type and thinning category) on wing haematomas: 6.99 (±1.78 SE) + 1.89 (±0.65)*average body weight (kg).

Regarding bird type, white-skinned birds had 30% more back haematomas and 8.7% more wing haematomas than yellow-skinned birds. Male broilers had 23.7% more back haematomas and 14.3% more wing haematomas than females. Males are generally heavier and have a longer wingspan, so they may be expected to have more wing bruises during catching and transport, when most bruises arise (Nijdam *et al.*, 2005). However, roaster females are quite small and had 32% higher back haematomas and 12% higher incidence of wing haematomas than broiler females. Back haematomas were less frequent in birds not thinned (NT), while wing haematomas were higher in T2, with a more marked effect in males.

The overall hypothesis of the current study was that rearing conditions and pre-slaughter handling can have important effects on FPD and carcass quality traits in broilers. The results appear to confirm this hypothesis, which suggests that the different handling procedures on the farm and pre-slaughter can be optimized to reduce the incidence of carcass quality defects, and thereby increase the welfare of these animals and improved product quality. The results also underline the important effects of thinning on carcass defects, especially in light of the lack of information in the literature.

References

Allain V, Mirabito L, Arnould C, Colas M, Le Bouquin S, Lupo C, Michel V, 2009. Skin lesions in broiler chickens measured at the slaughterhouse: relationships between lesions and between their prevalence and rearing factors. Brit Poult Sci 50: 407-417. https://doi.org/10.1080/00071660903110901

Baracho MS, Camargo GA, Lima AMC, Mentem JF, Moura DJ, Moreira J, Nääs IA, 2006. Variables impacting poultry meat quality from production to pre-slaughter: A review. Rev Bras Cienc Avic 8: 201-212. https://doi.org/10.1590/S1516-635X2006000400001

Bedanova I, Voslarova E, Chloupek P, Pistekova V, Suchy P, Blahova J, Dobsikova R, Vecerek V, 2007. Stress in broilers resulting from shackling. Poult Sci 86: 1065-1069. https://doi.org/10.1093/ps/86.6.1065

Bilgili SF, Hess JB, Blake JP, Macklin KS, Saenmahayak B, Sibley JL, 2009. Influence of bedding material on foot-pad dermatitis in broiler chickens. J Appl Poult Res 18: 583-589. https://doi.org/10.3382/japr.2009-00023

Broom DM, Reefmann N, 2005. Chicken welfare as indicated by lesions on carcases in supermarkets. Brit Poult Sci 46: 407-414. https://doi.org/10.1080/00071660500181149

De Jong IC, Van Harn J, Gunnink H, Hindle VA, Lourens A, 2012. Foot-pad dermatitis in Dutch broiler flocks: Prevalence and factors of influence. Poult Sci 9: 1569-1574. https://doi.org/10.3382/ps.2012-02156

Ekstrand C, Algers B, Svedberg J, 1997. Rearing conditions and foot-pad dermatitis in Swedish broiler chickens. Prev Vet Med 31: 167-174. https://doi.org/10.1016/S0167-5877(96)01145-2

Ekstrand C, Carpenter TE, Andersson I, Algers B, 1998. Prevalence and control of foot-pad dermatitis in broilers in Sweden. Br Poult Sci 39: 318-324. https://doi.org/10.1080/00071669888845

Elfadil AA, Vaillancourt JP, Meek AH, 1996. Impact of stocking density breed and feathering on the prevalence of abdominal skin scratches in broiler chickens. Avian Dis 40: 546-552. https://doi.org/10.2307/1592262

Estevez I, Newberry RC, Keeling LJ, 2002. Dynamics of aggression in the domestic fowl. Appl Anim Behav Sci 76: 307-325. https://doi.org/10.1016/S0168-1591(02)00013-8

Feddes JJ, Emmanuel EJ, Zuidhoft MJ. 2002. Broiler performance, body weight variance, feed and water intake, and carcass quality at different stocking densities. Poult Sci 81: 774-779. https://doi.org/10.1093/ps/81.6.774

Folegatti E, Sirri F, Meluzzi A, Toscani T, 2006. Prevalence of foot-pad lesions and carcass injuries as indicators of broiler welfare conditions in Italy. Proc 12th Eur Poult Conf, 10-14 Sept, Verona, Italy, pp: 303-307.

Gouveia KG, Vaz-Pires P, da Costa PM, 2009. Welfare assessment of broilers through examination of haematomas foot-pad dermatitis scratches and breast blisters at processing. Anim Welf 18: 43-48.

Greene JA, McCracken RM, Evans RT, 1985. A contact dermatitis of broilers: clinical and pathological findings. Avian Pathol 14: 23-38. https://doi.org/10.1080/03079458508436205

Hall AL, 2001. The effect of stocking density on the welfare and behaviour of broiler chickens reared commercially. Anim Welf 10: 23-40.

Hunter JM, Anders SA, Crowe T, Korver DR, Bench CJ, 2017. Practical assessment and management of foot-pad dermatitis in commercial broiler chickens: A field study. J Appl Poult Res 26: 593-604. https://doi.org/10.3382/japr/pfx019

Kaukonen E, Norring M, Valros A, 2016. Effect of litter quality on foot-pad dermatitis hock burns and breast blisters in broiler breeders during the production period. Avian Pathol 45: 667-673. https://doi.org/10.1080/03079457.2016.1197377

Knowles TG, Broom DM, 1990. The handling and transport of broilers and spent hens. Appl Anim Behav Sci 28: 75-91. https://doi.org/10.1016/0168-1591(90)90047-H

Martrenchar A, Boilletot E, Huonnic D, Pol F, 2002. Risk factors for foot-pad dermatitis in chicken and turkey broilers in France. Prev Vet Med 52: 213-226. https://doi.org/10.1016/S0167-5877(01)00259-8

Mitchell MA, Kettlewell PJ, 1994. Road transportation of broiler chickens: induction of physiological stress. Worlds Poult Sci J 50: 57-59. https://doi.org/10.1079/WPS19940006

Nijdam E, Arens P, Lambooij E, Decuypere E, Stegeman JA, 2004. Factors influencing bruises and mortality of broilers during catching transport and lairage. Poult Sci 83: 1610-1615. https://doi.org/10.1093/ps/83.9.1610

Nijdam E, Delezie E, Lambooij E, Nabuurs MJ, Decuypere E, Stegeman JA, 2005. Comparison of bruises and mortality, stress parameters, and meat quality in manually and mechanically caught broilers. Poult Sci 84: 467-474. https://doi.org/10.1093/ps/84.3.467

Oba A, Almeida MD, Pinheiro JW, Ida EI, Marchi DF, Soares AL, Shimokomaki M, 2009. The effect of management of transport and lairage conditions on broiler chicken breast meat quality and DOA (Death on Arrival). Braz Arch Biol Technol 52: 205-211. https://doi.org/10.1590/S1516-89132009000700026

Pagazaurtundua A, Warriss PD, 2006. Levels of foot-pad dermatitis in broiler chickens reared in 5 different systems. Brit Poult Sci 47: 529-532. https://doi.org/10.1080/00071660600963024

Pilecco M, Almeida Paz IDL, Tabaldi LA, Nääs IA, Garcia RG, Caldara FR, Andrela GO, 2012. Multi-Criteria analysis of the influence of rearing equipment and catching management practices on the incidence of back scratches in broilers. Rev Bras Cienc Avic 14: 275-282. https://doi.org/10.1590/S1516-635X2012000400007

Saraiva S, Saraiva C, Stilwell G, 2016. Feather conditions and clinical scores as indicators of broilers welfare at the slaughterhouse. Res Vet Sci 107: 75-79. https://doi.org/10.1016/j.rvsc.2016.05.005

Taira K, Nagai T, Obi T, Takase K, 2014. Effect of litter moisture on the development of foot-pad dermatitis in broiler chickens. J Vet Med Sci 76: 583-586. https://doi.org/10.1292/jvms.13-0321

Shepherd EM, Fairchild BD, 2010. Foot-pad dermatitis in poultry. Poult Sci 89: 2043-2051. https://doi.org/10.3382/ps.2010-00770

Villarroel M, Pomares F, Ibáñez MA, Lage A, Martínez-Guijarro P, Méndez J, de Blas C, 2018. Rearing, bird type and pre-slaughter transport conditions I. Effect on dead on arrival. Span J Agric Res 16 (2): e0503 (this issue). https://doi.org/10.5424/sjar/2018162-12013