RESEARCH ARTICLE

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 (<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).

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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).

| Bedding material | YEL-F | YEL-M | WHT-F | WHT-M | R-F |
|------------------|-------|-------|-------|-------|-----|
| 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. |
|-------------------------------------------------|--------|------|------|-------|--------|
| Shipmentsize (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)            | 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 (°C)                | 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   |
| Stacking density (animals/m²)                   | 11.8   | 2.17 | 6.07 | 18.9  | 18.4   |
| Stacking density (kg/m²)                        | 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.
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/m²) 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, up to a maximum value at 31°C, 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/m²) 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
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/m², but the decrease only

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

| Bird type | Thinning | 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|

[a] See Table 1 for abbreviations.  [b] 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.
Figure 2. Influence of stocking density on the incidence of (a) foot-pad dermatitis, (b) scratches, (c) back haematomas and (d) 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 |   |   |   |   |   |   |   |   |
|-------------------------|-----------|---|---|---|---|---|---|---|---|
|                         | YEL-F     | YEL-M | WHT-F | WHT-M | R-F | Y vs. W | M vs. F | Int | R-F vs. F |
| 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 |   |   |   |   |   |   |   |
|-------------------------|---------|---|---|---|---|---|---|---|
|                         | 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 haematoma          | 13.1    | 13.0 | 9.8  | <0.001   | 0.492  |
| Wing haematoma          | 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/m²) 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 than in white-skinned. When comparing T1 and T2, wing haematomas were higher for T1 and T2 compared to NT (Table 6). The aggregate of thinned birds 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.

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 practice 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/m² 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

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).
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/m²).

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.

Scrapes

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/m² 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/m²) 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/m², 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.

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