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RESEARCH ARTICLE

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Rearing, bird type and pre-slaughter transport conditions I. Effect on dead on arrival

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Abstract

The transport of broilers to slaughter normally results in a small percentage of dead on arrival (DoA) but little is known about the effects of flock thinning or bird weight. A multivariable linear model was used to analyse the incidence of DoA over one year in 1,856 flocks of Ross broilers (9,188 shipments). Each flock was categorized according to broiler type (yellow-skinned females and males, white-skinned females and males and roaster females) and thinning (birds transported after thinning, remaining birds after thinning and non-thinned flocks), in addition to transport distance, waiting time, maximum and minimum daily temperatures, precipitation and maximum wind speed. The overall percentage of DoA was 0.187%. The effect of the daily maximum outside temperature on DoA was quadratic with minimum DoA at 21.5ºC. Arrival time to the slaughterhouse and waiting time increased DoA by 0.0044% and 0.0021% for every 60 min increase, respectively. DoA were higher in males (which were heavier than females), and in the flocks that were previously thinned. An interaction between thinning and bird type was found, so that DoA were higher in previously thinned flocks of male broilers and roaster females. Despite the high incidence of thinning and larger bird weight, the percentage of DoA was comparable to previous studies. This research provides one of the largest detailed analyses of DoA in commercial broiler production in the Iberian Peninsula. The models described allow to quantify how increases in temperature, transport distance, waiting time, bird weight and the practise of thinning can all increase broiler mortality.

Additional keywords: poultry; slaughterhouse; mortality; welfare.

Abbreviations used: DoA (dead on arrival); NT (not thinned); R-F (roaster females); 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: FP, AL, PMG, JM. Analyzed the data: MAI, PMG, CdB. Drafted the MS: MV, MAI, CdB.

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Introduction

Transport to slaughter can have negative effects on the welfare of broilers (Mitchell & Kettlewell, 1998), often resulting in a small percentage of dead on arrival (DoA). According to Schwartzkopf-Genswein *et al.* (2012), the industry should aim to keep DoA below 0.20%, but several reports in the past decade have found higher mortalities (0.35% in Canada, Whiting *et al.*, 2007; or 0.37% in the Czech Republic, Vecerek *et al.*, 2016). Although a relatively low incidence overall, the wide relative variability suggests that several factors are at play. Those may include factors associated with variables on the farm, environmental conditions (*e.g.*, temperature and humidity), transport conditions (*e.g.*, distance travelled; Oba *et al.*, 2009), waiting time, and animal based variables such as genotype, sex and live-weight (Nijdam *et al.*, 2004; Chauvin *et al.*, 2011; Jacobs *et al.*, 2016a, b; Kittelsen *et al.*, 2017).

In terms of handling, there is little data on the effect of flock thinning, where a first group of birds is removed from the main flock and taken to slaughter a number of days before the second group. Thinning has been linked to increased infection of *Campylobacter jejuni* in the birds that remain on the farm (Koolman *et al.*, 2014) but few studies have considered its effect on DoA.

Thinning is also related to genotype and sex, since faster growing birds will be thinned more (Chauvin *et al.*, 2011). Previous studies have considered bird weight and age (*e.g.*, Haslam *et al.*, 2008), but not as many have described DoA in terms of bird sex. Furthermore, final bird slaughter weight and bird type vary from year to year and among countries, forcing adjustments in handling techniques, such as thinning. In this study, we used a one-year database to analyze the effects of those different factors on DoA in a commercial setting. In a second paper in this series we also consider the effects of rearing parameters, bird type and pre-slaughter handling on the incidence of foot-pad dermatitis and carcass defects (Villarroel *et al.*, 2018).

Material and methods

Animals and shipments

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. The dataset included details about broiler transport and bird types. 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). Each type (and sex) was bred separately. The total number of shipments for each type of bird and the average slaughter weights are shown in Table 1. Overall, 73% of all flocks were thinned. In the case of males, thinning meant that one group of birds (T1), representing a proportion of the total flock (normally around 25% of birds) was taken to slaughter, and 4-6 d later the second and final group was taken (T2). In the case of females, the R-F type was almost always thinned and the T1 was normally large (around 30%) and transported 8-11 d before T2 to produce a specific product (*i.e.*, roasters). The distribution of shipments in terms of thinning and bird type is summarized in Table 1. When drawing the frequency diagrams of average slaughter weights per shipment (Figure 1), it can be deduced that the non-roaster females were rarely thinned, representing only 6.25% of all thinned birds (WHT-F and YEL-F). Most of the thinned birds were males (63.2% for WHT-M and YEL-M) or R-F (30.6%).

Each shipment was defined as the movement of one transport vehicle (*i.e.*, truck) from the farm to the slaughterhouse. Each flock may have needed several shipments depending on the size of the farm. For each shipment the company supplied us with information that was related to either handling conditions or more animal-based criteria. That included the DoA, bird type/sex and slaughter weight per journey as well as the date/week of transport, and other data which are explained below. Daily weather data (maximum and minimum daily temperatures, precipitation and maximum wind speed) were collected from a site near the slaughterhouse supplied by the Spanish Meteorological Agency (*Agencia Estatal de Meteorología,* http://www.aemet.es), including maximum and minimum daily temperatures, precipitation and maximum wind speed.

Handling conditions included distance travelled (in km), the arrival time (to the slaughterhouse) and hours waited to unload. The arrival time was noted in minutes after 20:00 h (minute 0) the day before slaughter (which was when the first shipment arrived). The waiting time included both time spent on the truck before unloading and a short (but untimed) lairage in a conditioned waiting area before slaughter (where birds were still in the drawer module). The

Table 1. Total shipments and average characteristics of shipments with respect to transport conditions, average weight and proportion of thinning for the different bird types.

Bird type [1]	Total shipments	Distance (km)[2]	Arrival (min)[3]	Waiting (min)[4]	Weight (kg)[5]	Thinned (%) [6]		
						T1	T2	NT
YEL-F	1,662	50.8	357	166	2.44	4.4	16.1	79.4
YEL-M	679	53.5	840	180	3.18	25.6	59.4	15.0
WHT-F	680	47.3	686	184	2.51	2.6	7.1	90.3
WHT-M	4,452	58.8	603	182	3.12	19.0	71.7	9.3
R-F	1,715	54.9	669	170	2.28	26.0	71.9	2.1

[1] YEL-F= yellow-skinned female, YEL-M = yellow-skinned male, WHT-F = white-skinned female, WHT-M = white-skinned males, R-F = roaster females. [2] Distance travelled from the farm to the slaughterhouse. [3] Arrival time to the slaughterhouse where minute 0 was 20:00 h the night before slaughter. [4] Waiting time at the slaughterhouse before slaughter. [5] The average slaughter weight of each broiler type. [6] The percentage of birds thinned, where T1 = birds transported after thinning, T2 = remaining birds after thinning, NT = non-thinned flocks.

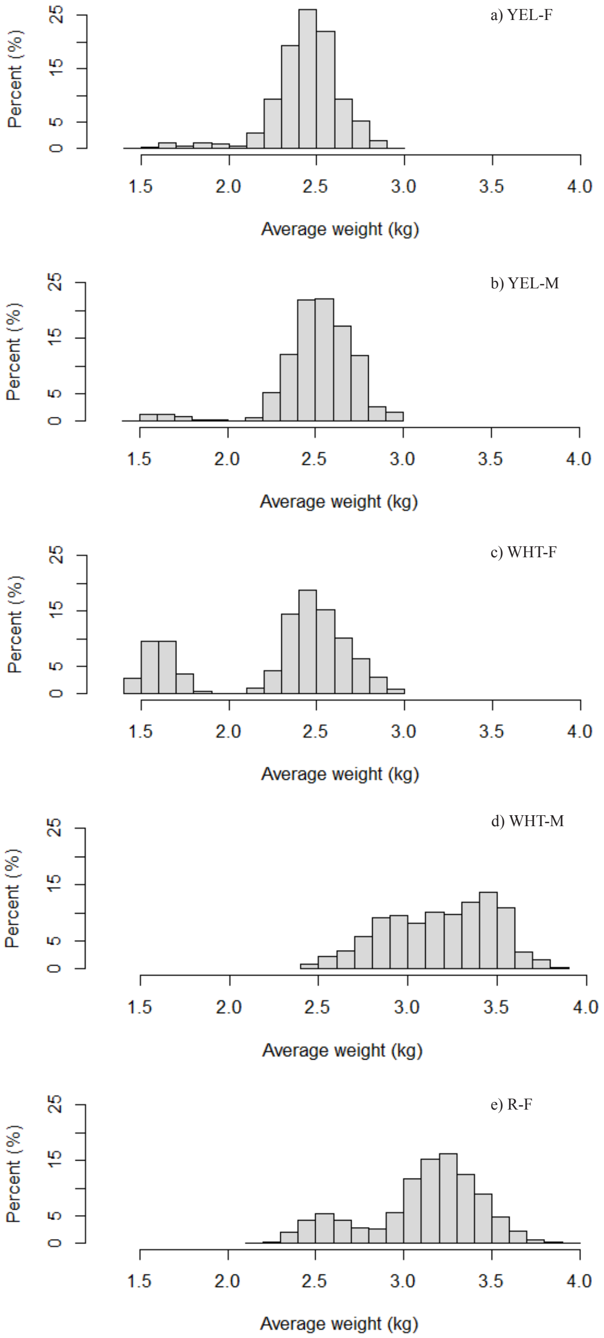

Figure 1. Distribution of average slaughter weights of the different categories of chickens transported: a) yellow-skinned females; b) yellow-skinned males; c) white-skinned females; d) white-skinned males, and e) roaster females.

average characteristics per shipment are shown in Table 1 for each bird type. On average, birds were fasted for 6 h before loading. The loading of the birds was performed using a module with drawers, which was taken directly from the truck into the farmhouse by forklift (birds were caught manually and put into the drawers) and once the module was full, it was taken back to the truck. The density of the birds in each transport crate was similar for all shipments (45 kg live weight/cage, where cages measured 1.16 m long, 0.76 m wide and 0.255 m high). The number of DoA was information supplied by the slaughterhouse and obtained by counting dead birds after unloading each shipment at the slaughterhouse.

Data processing and statistical methods

The original file contained 2,342 flocks and 11,560 shipments. We eliminated shipments made before 19 January 2015 or after 15 February 2016 since we did not know whether they had been thinned or the second shipment had not yet occurred. We did not use shipments where the DoA were abnormally high (above 1% DoA, n=38), since they were considered exceptional cases and not related to the production system or transport conditions. After data cleansing, the file contained 35,518,924 birds from 1,856 flocks and 9,188 shipments. DoA were analyzed using the multivariable linear model of the GLM program of SAS (v9, 2002). The experimental unit was the shipment. The independent variables included both categorical (bird type, thinning), and continuous variables (maximum and minimum daily temperatures, precipitation, maximum wind speed, live weight, arrival time and waiting time). The averages, ranges, standard deviations and coefficient of variations of all the continuous variables studied are shown in Table 2. The effect of the interval of days between the first thinning and final shipment was also analyzed. The effects of weather conditions were analyzed using polynomial regressions. Interactions among all variables were also considered in the model.

For the analysis of variance we used the 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. This procedure is justified by the fact that, as mentioned above, some of the independent variables were not distributed uniformly among the different types of birds. For instance, the average broiler weight and the frequency of thinning varied among bird types, and also the hour of entry and the waiting time were different depending on logistic requirements (Table 1). For that reason, the adjustment was made within

Table 2. Descriptive statistics of the variables used in the statistical model for all shipments (n=9188 shipments).

Traits	Average	SD[3]	Min	Max	CV%[4]
Shipment size (number of birds/truck)	3,852	1,100	1,001	6,336	28.6
Dependent variables (%)					
DoA[1]	0.181	0.129	0.0	0.994	71.6
Independent variables					
Maximum outside temperature (ºC)	22.1	7.52	7.6	40.1	34.1
Minimum outside temperature (ºC)	9.53	5.22	-3.3	21.6	54.7
Distance from farm to slaughterhouse (km)	55.4	20.6	8.0	119	37.4
Arrival time to slaughterhouse (min) [2]	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	17.6

[1] DoA= dead on arrival. [2] For arrival time to slaughterhouse, minute 0 was 20:00 the night before slaughter. [3] SD = standard deviation. [4] CV% = coefficient of variation expressed in percentage.

each category in order to reflect the typical farm conditions.

Results

Handling conditions

In Table 3 we show the estimated regression coefficients of the continuous variables that had a significant influence on DoA in the statistical analysis. The effect of maximum daily temperatures on DoA was quadratic. Based on the linear and quadratic coefficients in Table 3, the minimum DoA occurred at 21.5ºC. An increase or decrease of 5ºC with respect to the optimal temperature resulted in an increase in absolute DoA of 0.0077 percentage units. The longer the distance from farm to slaughterhouse, the greater (p<0.0001) the DoA (by 0.036% per each increase in 50 km). We found no significant effects of precipitation or maximum wind speed. The average arrival time for all bird types was 6:00 h. DoA increased significantly (p<0.0001) by 0.0044 percentage units for every extra hour in arrival time. Waiting time before unloading also had a significant effect (p<0.0001), increasing the mean DoA by 11.6% for every 60 min increment. We did not observe any significant interaction between the waiting time and arrival time.

Animal-based variables

Arrival time, waiting time, average weight and the incidence of thinning varied according to bird type. In Table 1 we can appreciate how YEL-F normally arrived first. In this case, if we estimate DoA by establishing one common arrival time (the average for all the vehicles), the estimated DoA of YEL-F would be higher than the real handling practices for that bird type. Accordingly, the following analyses were carried out using the values calculated with the BYLEVEL option to reflect the real values of the continuous variables for each bird type (transport conditions and average weight).

Table 3. Significant effect of the continuous variables studied regarding dead on arrival (DoA).

Factor	Coefficient	SE[2]	p[3]
Intercept	-0.161	0.039	<0.0001
Maximum temperature (ºC)	$-84.5 \cdot 10^{-4}$	$1.781 \cdot 10^{-3}$	0.0178
Maximum temperature [1] (ºC)	$19.6 \cdot 10^{-5}$	$3.76 \cdot 10^{-5}$	<0.0001
Distance (km)	$72.9 \cdot 10^{-5}$	$1.09 \cdot 10^{-4}$	<0.0001
Arrival time (min)	$7.3 \cdot 10^{-5}$	$1.58 \cdot 10^{-5}$	<0.0001
Waiting time (min)	$34.9 \cdot 10^{-5}$	$2.60 \cdot 10^{-5}$	<0.0001
Average weight (kg)	0.101	0.0121	<0.0001

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

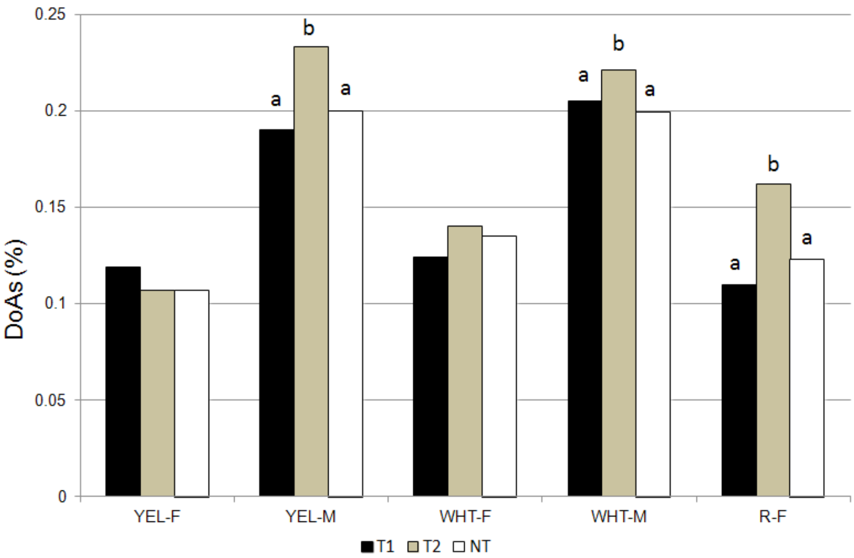

Figure 2. Influence of thinning (T1 = birds transported after thinning, T2 = remaining birds after thinning, NT = non-thinned flocks) on the percentage of dead on arrival (DoA) according to different bird types (see Table 1 for abbreviations). Bars with different letters are significantly different p<0.05 (SD = 0.117).

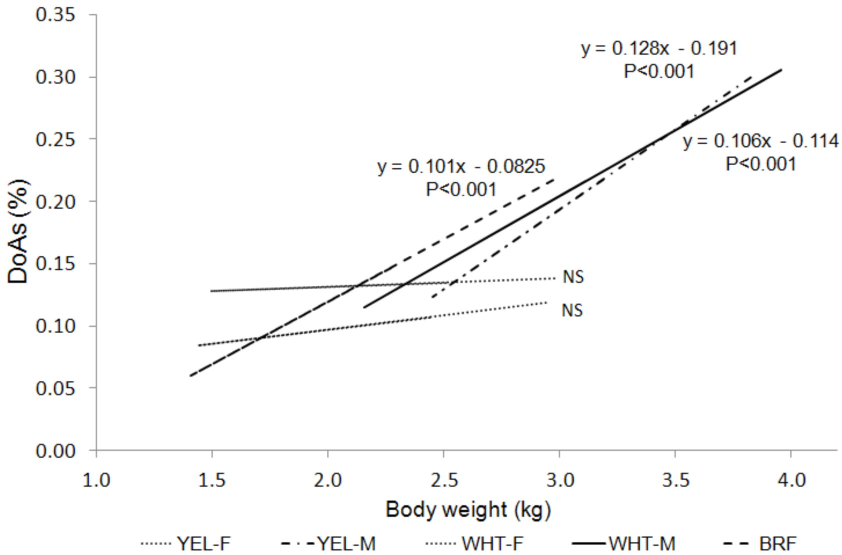

Figure 3. Influence of average live weight (kg) on dead on arrival (DoA) according to bird type (see Table 1 for abbreviations).

An interaction was observed between bird type and thinning (p=0.0146; see Fig. 2). The DoA increased in T2 with respect to T1 and NT for males and especially for R-F, but no effects were observed in broiler females. For all bird types, DoA did not differ between T1 and NT. The influence of the average weight and its interaction (p<0.0001) with bird type is shown in Fig. 3. DoA increased linearly with slaughter weight for males in both categories (YEL-M and WHT-M) and in R-F. However, slaughter weight did not have a significant influence on DoA for the other groups of females (*i.e.*, YEL-F and WHT-F).

Discussion

In this study, we used a one-year commercial database to analyze the effects of different factors on DoA. According to the results, increases in temperature, transport distance, waiting time, bird weight and thinning can all significantly increase DoA. Depending on its duration and the environmental conditions, transport can compromise the thermoregulation of birds, ultimately causing death. In the current study, DoA were lowest when the maximum outside temperature on the day of transport was 21.5ºC, but the effect of the minimum temperature was not significant. That temperature is within the zone of normothermia for adult birds (from 18ºC to 24ºC, Sturkie, 1965). More than 30 years ago, Meltzer (1983) proposed two equations that related lower critical temperatures for male and female broilers based on weight. Based on those equations and for the weights of the birds in the current study, the lower critical temperature for the males and females would be 20.9ºC and 21.6ºC, respectively, which is close to 21.5ºC, the outside temperature when DoA were the lowest. Also, previous studies regarding DoA report more deaths during the hottest and coldest months. For example, Nijdam *et al.* (2004) found that DoA increased significantly with temperatures were below 5ºC and above 15ºC, with the lowest DoA occurring in fall and spring, as also occurred in the current study.

We also found a linear increase of DoA with distance to the slaughterhouse (*i.e.*, transport time) of 0.036% for each increment in 50 km in a range of 8-119 km. This value is similar to that found by Vecerek *et al.* (2006) for distances less than 200 km, although they also found higher DoA (0.862%) when distances were greater than 300 km. However, only a trend (p=0.08) for higher DoA was found by Chauvin *et al.* (2011) when the distance between farm and slaughterhouse increases. Regarding arrival time to the slaughterhouse, there is little information available in the literature. Our model suggests that the amount of DoA increased in shipments that arrived later, although the reasons for this are unclear and may also be tied with bird type. The average waiting time was 177 min, ranging from 15-681 min. In this interval the DoA increased linearly, which is in agreement with other authors (Nijdam *et al.*, 2004; Chauvin *et al.*, 2011). As opposed to arrival time, here there was less relation between waiting time and bird type.

The results suggest that DoA were higher for T2 in comparison to T1 and NT flocks. Chauvin *et al.* (2011), one of the few other studies to look at the effect of thinning in broiler DoA, also found significantly higher (p=0.001) DoA in the second shipment. That could be related to the need to fast all the animals in the flock at the time of the first thinning and the fast again before the following transport. The effect could be worsened in the case of R-F than in male broilers since there was a longer time between shipments (on average 9.5 d compared to 5 d for males). Also, Koolman *et al.* (2014) found that thinning increased the campylobacter count and its prevalence in the cecum of birds from the second shipment compared to the first one. However, that effect was confounded with the increase in bird weight and several reports have found that bacterial counts are higher in older birds (Bouwknegt *et al.*, 2004; Barrios *et al.*, 2006; Chowdhury *et al.*, 2012).

The birds used in our study had a higher average weight (overall average of 2.81 kg, range 1.41-3.96), compared to other studies (for example, an average of 2.44. kg in Nijdam *et al.*, 2004, and 1.9 kg in Chauvin *et al.*, 2011). In general, DoA was higher for larger birds, which coincides with Nijdam *et al.* (2004), who found a linear increase in DoA with live weight. However, they did not look at the interaction between live weight and bird sex. In our case, the effect of weight on DoA differed among bird types, with a linear increase in males and roasters but not in non-roaster females. In the case of male broilers this interaction might be explained by their higher live-weight gain, which may impose a higher metabolic load in the heaviest birds. Haslam *et al.* (2008) also report a higher incidence of DoA in heavier birds. For roaster females, the higher DoA with increased weight may be since the highest weights were associated with the T2 group, which were more stressed.

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