

Effect of environmental conditions during transport on chick weight loss and mortality

M. Yerpes,¹ P. Llonch, and X. Manteca

Animal Nutrition and Welfare Service, Department of Animal and Food Science, Facultat de Veterinària, Universitat Autònoma de Barcelona, Bellaterra E-08193, Barcelona, Spain

ABSTRACT The present study had 2 objectives: the first was to analyze the possible impact of transport on weight loss and mortality during transport, and first-week mortality. The second was to monitor the environmental condition (i.e., temperature, humidity, and so on) variability during transport with an effect on day-old chicks. Probe equipment was installed in a truck of a poultry company from Spain, including a total of 66 journeys made in commercial conditions between May and November 2017. Animal-based measures collected included BW (before and after transport), mortality during transport, mortality during the first week of life, which were contrasted against a series of environmental variables including air temperature, RH, and carbon dioxide (CO₂) atmospheric concentration for every journey, number of day-old chicks (%) per journey, transport duration (h), zones inside the loading area (zone 1, near to the cabin; zone 2, in the central point; and zone 3, close to the back doors), height (1, top; 2, medium; and 3, bottom), mo-

(May to November), number of stops, type of stop during journey (farm stops and driver stops), time to start the journey, as well as other intrinsic factors of chicks (gender, breed [Ross and Cobb], breeder flock age [wk] and egg storage day). Because the database included random factors, longitudinal data, and repeated measures, a multivariate model was used to analyze the data. The results showed that chick weight loss was positively associated with journey duration and RH. No effect of environmental variables was found on mortality during transport. However, chick mortality during the first week of life was related with the percentage of day-old chicks loaded per journey and chick gender. In conclusion, owing to the environmental heterogeneity during transport and the effect of the environment on chick weight during transport and mortality at first week of life, there is an urgent need to refine the air-conditioning and ventilation systems of day-old chick transport toward a greater environmental homogeneity.

Key words: transport, broiler, day-old chick, performance, animal welfare

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INTRODUCTION

The transport of live animals is considered a great source of stress (Mitchell, 2009), owing to the exposition to a variety of potential stressors involved, such as ambient temperature, acceleration, vibration, noise, space restrictions, and air pollutants (Mitchell and Kettlewell, 1993; Mitchell, 2009). In accordance with the 2019 statistics of the Spanish Ministry of Agriculture, Fisheries and Food and the European Commission, 628 million of chicks produced in Spain and 6,700 million of chicks produced in Europe most of them undergoes the

transportation when they are 1 d of age. Despite efforts to improve the transportation process, they are still transported for extended periods under suboptimal environment conditions (Bergoug et al., 2013; Jacobs et al., 2016). Although in recent years there have been ever-increasing progress in using sensing devices toward improved poultry welfare (Neethirajan, 2017; Murillo et al., 2020; Nazareno et al., 2020), there are still many knowledge gaps, such as the adequate level of carbon dioxide (CO₂) during transport, or the interaction between environmental variables (temperature, relative humidity, or CO₂).

In addition to these knowledge gaps, chicks are neonatal animals with an immature physiology (Shinder et al., 2007; Yassin et al., 2009), and they are exposed to many challenges during transportation. From hatching to arriving at the farm, they can be deprived from feed or water for more than 72 h, and this would not be in line with the Council Regulation

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¹Corresponding author: martayerpes@gmail.com

(EC) No 1/2005. Hatching can range few hours within the same flock (up to 48 h), which may result in some chicks being deprived of feed and water for longer than others within the same flock (Jacobs et al., 2016). Feed and water deprivation have been proven to negatively affect performance (Decuyper et al., 2001). Despite chicks being believed to sustain themselves without feed or water for 72 h after hatching by using reserves in their yolk sac (EFSA, 2011), modern genetic lines with high growth and metabolic rates may deplete their energy reserves more quickly (EFSA, 2011). In addition, the transportation process could exacerbate the depletion of reserves and dehydration, through excessive thermoregulatory demands and stress, thus possibly affecting chicks' BW and mortality rates (Bergoug et al., 2013; EFSA, 2012; Jacobs et al., 2016, 2017). In fact, chick mortality during first week of life can reflect the stress of transportation process (Bayliss and Hinton, 1990; Yassin et al., 2009).

Given the impact of transport, the general aim of this study was to assess the conditions during transport that may affect broiler chick's welfare and performance in Spain. To respond to this objective, 2 phases were carried out: 1) to analyze the possible impact of transport on weight loss and mortality during transport; and first-week mortality and 2) to monitor the environmental conditions (i.e., temperature, humidity, and so on) variability during transport with an effect on day-old chicks.

MATERIALS AND METHODS

This study was conducted in cooperation with a broiler hatchery from Spain. Sixty-six journeys were monitored from May to November 2017. The study was divided into 2 phases, phase I was carried out during 10 journeys that were used to investigate the association between the environmental conditions inside the container (air temperature, RH, and CO₂ levels) and chick weight loss during transport, mortality during transport, and first-week mortality. In 56 journeys for phase II, the environmental variables found to affect chick's growth and/or survival during phase I were monitored. Data on the environmental conditions inside the truck were monitored using a digital probe equipment (model TRUCK RHT; Sinergia G6) always with the same truck and driver. The equipment consisted of 1 data logger, 27 probes for temperature (T^a) (°C) and RH (%) and 1 CO₂ probe (ppm). Sensors recorded parameters in 45-s intervals and sent the information to the data logger via digital radio, so the data logger was used as a receiver for the probe readings. Then, the data logger sends the information to a Web portal thanks to a remote connection via 3G/4G, allowing access to data in real-time.

Truck

The trailer used to transport chicks was 13 × 3 × 2.5 m long, wide and high, respectively. It

was equipped with thermal isolation of expanded polyurethane and had an internal and external structure coated with aluminum. The trailer had 2 back doors with nonhermetic enclosure. The inner door was a sailcloth sliding curtain, and the outer door was a lifting platform. The sliding curtain was kept closed during journeys and only open when chicks were unloaded. The trailer load was distributed in 5 rows of trolleys along the truck with a 10-cm space between them (Figure 1). The load capacity was 750 boxes with 100 chicks per box approximately, which makes an average number of 150,000 chicks per journey. Inside the container, 2 probes were part of the truck's equipment and were located on the roof to record the environmental temperature. The temperature of the trailer was automatically controlled at 27°C ± 2 using fans for ventilation. The air inlets were distributed along the sides of the container roof, and the air exits (ventilation) were located in the central area of the roof in the form of a grid with filter.

Day-Old Chick Boxes

Chicks were transported in fully perforated plastic boxes (60 × 40 × 15 cm) following regular procedures in commercial transports (Council Regulation, EC 1/2005). Every day-old chick trolley carried 28 boxes distributed in 2 columns of 14 boxes (Figure 2).

Data Collection

Phase I In the first 10 journeys the loss of weight and the mortality during transport and first-week mortality were monitored. For every journey, 27 boxes of day-old chicks were monitored using 27 T^a and RH probes. The distribution of the T^a and RH probes was different in every journey because the day-old chicks' boxes were randomly selected. The probes were installed in the day-old chick trolleys considering 3 height points (Figure 2), and the height of the probes remained constant in all the journeys.

The CO₂ probe was located at the central point of the container at the bottom height (Figure 1). The 27 boxes were randomly selected in the hatchery before every journey, and after loading the chicks, they were weighed (scale model NVL20000 Navigator XL; OHAUS) and the number of chicks recorded. On arrival at the farm, the boxes were weighed once again, and the number of dead chicks was recorded. In addition to temperature, RH, and CO₂, the environmental variables considered were time to start the journey, journey duration (h), number and type of stops during journey (farm stops and driver stops), number of chicks (%) per journey, and mo. Animal-based response variables recorded during the study were weight loss and number of dead chicks during transport and dead chicks during the first week of life.

The company provided data on the following breeding and husbandry variables for each flock: flock ID, breed (Ross or Cobb), egg storage (d), breeder flock age

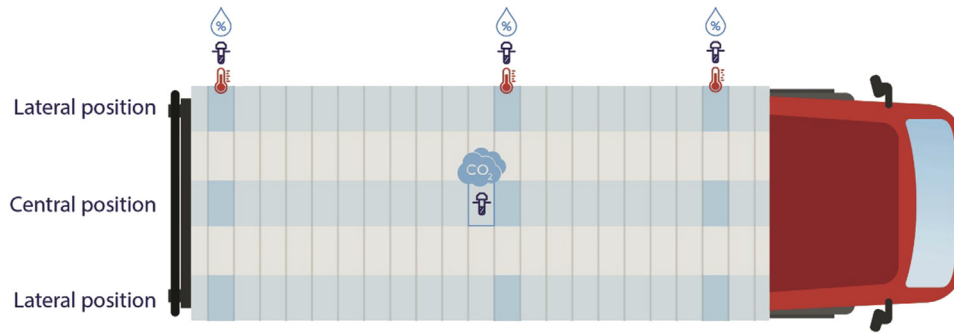


Figure 1. Air view of the truck, highlighting the center and lateral rows. The colored squares represent the boxes with temperature and RH probes. The red cross indicates the position of the CO₂ probe.

(wk), chick gender, and farm (house reference). The age of the breeders was categorized as per the [Cobb guide \(2008\)](#): ≤ 33 wk (young breeders), 34–50 wk (adult breeders), and ≥ 51 wk (old breeders).

Phase II In Phase II, the following 56 journeys were used to monitor the environmental profile inside the container. Probes of T^a and RH were distributed in 3 zones among the container: zone 1, near to the cabin; zone 2, in the central point; and zone 3, close to the back doors ([Figure 3](#)). This probes' distribution

allowed the monitorization of potential differences between zones and positions (comparing the central row with the 2 sides of the container) in the container ([Figure 1](#)). This setup allowed controlling 3 of 5 trolleys that were distributed horizontally at 3 different height points (top, medium, and bottom), following the same distribution as in the first 10 journeys ([Figure 2](#)).

Statistical Analysis

Statistical analysis was carried out using the statistical software SAS v9.4 (SAS Institute Inc., Cary, NC), for Windows. The significance level was set at $P < 0.05$. The experimental unit was each journey. Data on T^a, RH, and CO₂ were normally distributed, based on the graphical evaluation of the residuals (histogram and Q–Q plot). To respond the 2 objectives of the study, the statistical analysis was carried out in 2 parts, following the steps described in the following.

In phase I, a bivariate linear regression analysis was carried out between fixed effects and response variables, and a correlation study between continuous variables was assessed using Pearson correlation coefficient. Because the database included random factors, longitudinal data, and repeated measures, a multivariate model was used. The fixed effects considered in phase I analysis were T^a (°C), RH (%), CO₂ (ppm), percentage of day-old chicks loaded per journey (%), transport duration (h), height (1, top; 2, medium; and 3, bottom), mo (May to November), number of stops, type of stop during journey (farm stops and driver stops), time to start the journey, chick gender, breed (Ross and Cobb), breeder flock age (wk), and egg storage (d). The response variables were weight loss (%) and mortality (%) during transport and at first week of life.

In phase II, a bivariate linear regression analysis was carried out between fixed effects and response variables, and a correlation study between air temperature and RH was assessed using Pearson correlation coefficient. A multivariate model was used, and the fixed effects considered were the environmental variables including number of day-old chicks (%) per journey, transport duration (h), zones inside the loading area (zone 1, near to the cabin; zone 2, in the central point; and zone 3, close to the back doors), position inside load

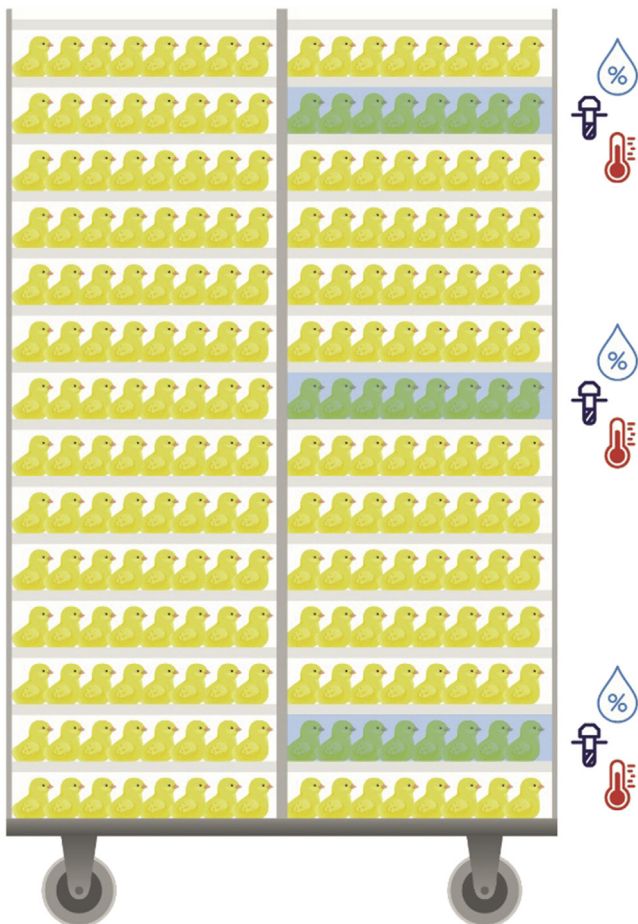


Figure 2. Lateral view of day-old chick trolley inside the truck. Distribution of the temperature and RH probes inside the day-old chick trolley. The colored squares were the boxes with temperature and RH probes.

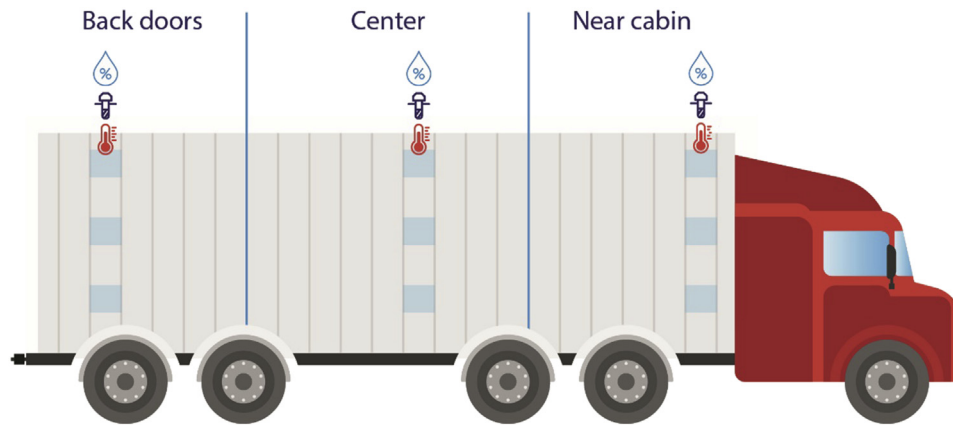


Figure 3. Lateral view of the truck. Distribution of the temperature and RH probes inside the container. The colored squares were the boxes with temperature and RH probes.

area (0, central row; 1, lateral rows), height (1, top; 2, middle; and 3, bottom), mo (May to October), number and type of stops during journey, and start time of the journey. The response variables were temperature ($^{\circ}\text{C}$) and RH (%). In addition, the following interactions were considered in the multivariate model of phase II: height*position, height*zone, position*zone.

Finally, for the 2 phases, each journey was considered a random factor, and the variables were manually removed one by one from the model following a step-wise manner using a significance level of 0.05 as reference. The P -values of multiple comparisons were adjusted with the Tukey correction. The results will be presented using SD and the abbreviation \pm for SE.

RESULTS

Phase I

Weight Loss During Transport During transport, the mean weight loss of the chicks was 2.96% (SD = 1.22). The correlation between chick weight loss and the continuous variables was weak for most variables; it seemed that the CO_2 level have a negative correlation with chick weight loss but it was not significant. Another variable that had a positive correlation with chick weight loss was journey duration; in this case, the correlation was significant (Table 1). The variables showing an effect over weight loss during transport were journey duration ($P = 0.0006$) and RH ($P = 0.0188$) (Table 2). The estimated effect of journey duration and RH level over weight loss was $-0.2407 (\pm 0.06889)$ and $-0.07745 (\pm 0.03269)$, respectively. The environmental T^a , CO_2 , the percentage of day-old chicks loaded per journey, height inside the trolley, mo, number of stops, type of stop during journey, time to start the journey, and the breeding variables did not show a significant effect on weight loss during transport (Table 2).

Chick Mortality During Transport and at First Week of Life Mean chick mortality during transport was 0.055% (SD = 0.043), which is equivalent to 15 dead chicks of 27,031 chicks monitored. The statistical

analysis of this variable could not be carried out owing to the low incidence of mortality during transport.

Chicks mean mortality during the first week of life was 2.02% (SD = 1.21). The correlation between chick mortality at first week of life and the continuous variables was weak and not significant for any of them (Table 1). The percentage of day-old chicks loaded per journey (%) and chick gender had effect on chick mortality during the first week of life ($P = 0.0082$ and $P = 0.0087$, respectively). The higher the percentage of chicks loaded in the truck, the higher the mortality (estimate = 0.305 ± 0.114) was observed. As for chick gender, male chicks (estimate = 0.607 ± 0.052) had the highest mortality rate, followed by mixed chicks (estimate = 0.541 ± 0.099), and females (estimate = 0.498 ± 0.049) had the lowest mortality

Table 1. Results for Pearson correlation coefficients and P -values for the dependent variables (chick weight loss during transport, mortality at first week of life, and RH) and continuous variables considered in the study.

Pearson Correlation Coefficients		
Prob > r under H0: Rho = 0		
Weight loss		
Effect	Corr.	P -value
Temperature	-0.09999	0.1375
HR	0.12800	0.0569
CO_2	-0.8773	0.2443
Time to start the journey	-0.1479	0.0228
Journey duration	0.46479	<0.0001
Percentage of chicks loaded per journey	-0.02285	0.7487
Breeder flock age (wk)	-0.00474	0.9421
Egg storage (d)	-0.07276	0.2928
Mortality at first week of life		
Temperature	0.00646	0.9132
HR	-0.09725	0.1001
CO_2	0.14695	0.0342
Time to start the journey	0.05456	0.1258
Journey duration	0.03309	0.5753
Percentage of chicks loaded per journey	0.13148	0.0251
Breeder flock age (wk)	0.3254	0.0568
Egg storage (d)	0.2156	0.0687
RH		
Temperature	-0.5532	0.0001

Table 2. Results from the multivariate model used to analyzed the effect of the independent variables under study over the chick weight loss during transport (10 journeys, May to November, 2017, Spain).

Type III tests of fixed effects				
Effect	Num DF	Den DF	F value	Pr > F
Month	5	111	0.37	0.8674
Height inside the trolley	2	111	0.71	0.4955
Time to start the journey	1	111	0.37	0.5417
Journey duration	1	111	7.28	0.0006
Number of stops during journey	2	111	2.06	0.1327
Percentage of DOC per journey	1	111	0.65	0.4226
Chick gender	1	111	0.52	0.4711
Temperature	1	111	0.22	0.6390
RH	1	111	2.95	0.0188
CO ₂	1	111	2.89	0.0921

rate. The environment variables, journey duration, height inside the trolley, mo, number of stops, type of stop during journey, and time to start the journey and the other breeding variables did not have a significant effect on first-week mortality (Table 3).

Phase II

Microclimate Profile The container was at 29.38°C (SD = 0.97) temperature and 47.97% (SD = 4.43) humidity. Table 4 shows the descriptive analysis of the average T^a and RH in the container, as per zone, position inside the container, and height inside the trolley.

RH The results showed that the RH was different among heights inside the trolley (upper, middle, and bottom), positions (central and lateral rows), and zones (zone 1, near to the cabin; zone 2, in the central point; and zone 3, close to the back doors) inside the container (all $P < 0.05$). Related to height inside the trolley, upper height had a higher RH (estimate = 49.22% ± 0.628) than middle (estimate = 46.80% ± 0.627) and bottom (estimate = 47.95% ± 0.628) height. In the case of positions inside the container, the central row showed a lower RH (estimate = 47.41% ± 0.615) than lateral rows (estimate = 48.57% ± 0.615). Regarding zones inside the container, zone 1 (near to the cabin) showed a lower RH (estimate = 46.50% ± 0.638) than zones 2 (in the central point) (estimate = 48.56% ± 0.625; $P < 0.001$) and 3 (close to the back doors) (estimate = 48.90% ± 0.624; $P < 0.001$), whereas no

significant differences were found between zone 2 (in the central point) vs. 3 (close to the back doors). The differences in RH between zones inside the container varied more than 2%, being zone 3 (close to the back doors) the most heterogeneous. The interaction height*position was significant ($P < 0.0001$), which means that the RH at certain height inside the trolley was different depending on the position (row) inside the container, reaching differences of more than 5% within the same height inside the trolley among positions inside the container (Figure 4). These patterns could be related to the association between air T^a and RH (Table 4), which means that when air temperature was high, RH was low and vice versa. The association between T^a and RH makes that variations in T^a among locations inside the container impacted the RH.

No differences in RH levels were detected as per journey duration (h), type of truck stop during journey, and percentage of day-old chicks per journey (%). However, differences were detected between mo for the RH levels ($P = 0.0265$), being August and September the mo with the highest RH levels (mean = 49.40 SD = 3.47 and 50.51 SD = 4.95; respectively) compared with May, June, and July (mean = 46.16 SD = 3.49, 46.82 SD = 4.55, and 45.92 SD = 4.08; respectively).

Air temperature The results showed that the temperature was different among heights inside the trolley (upper, middle, and bottom), positions (central and lateral rows), and zones (zone 1, near to the cabin; zone 2, in the central point; and zone 3, close to the back doors)

Table 3. Results from the multivariate model used to analyzed the effect of the independent variables under study over the chick mortality during the first week of life (10 journeys, May to November, 2017, Spain).

Type III tests of fixed effects				
Effect	Num DF	Den DF	F value	Pr > F
Month	4	123	0.59	0.6719
Chick gender	2	123	1.87	0.1578
Number of stops during journey	2	123	1.35	0.2626
Time to start the journey	1	123	0.71	0.4016
Percentage of DOC per journey	1	123	0.68	0.4098
Journey duration	1	123	0.02	0.8913
Temperature	1	123	1.40	0.2395
RH	1	123	0.78	0.3787
CO ₂	1	123	0.39	0.5330
Type of stops during journey	1	123	1.68	0.1974

Table 4. Descriptive analysis of the average air temperature and RH inside the container of the truck by zones (1, near cabin; 2, center container load; and 3, back doors), position (central row, lateral rows), and height (1, upper; 2, middle; and 3- bottom).

Variables	Mean	SD	Min.	Max.	<i>P</i> -value
Air temperature (°C)					
Height					
Upper	28.80	0.971	25.88	31.04	<0.0001
Middle	29.92	1.122	27.55	32.67	
Bottom	29.41	1.019	26.50	31.38	
Zones					
Near cabin	30.19	1.186	25.43	33.11	<0.0001
Center	28.80	1.434	25.62	31.00	
Back doors	29.01	1.458	25.37	31.97	
Positions					
Lateral rows	29.07	0.948	26.66	31.24	<0.0001
Central row	29.96	1.320	26.53	32.71	
RH (%)					
Height					
Upper	48.82	4.643	40.91	59.08	<0.0001
Middle	46.81	4.589	38.95	58.12	
Bottom	48.29	4.307	40.50	57.63	
Zones					
Near cabin	47.24	4.621	38.27	60.63	0.0028
Center	48.75	5.596	39.73	61.37	
Back doors	49.06	5.645	38.61	63.85	
Positions					
Lateral rows	48.38	4.307	40.10	57.47	<0.0001
Central row	47.20	4.900	38.86	60.31	

inside the container (all $P < 0.0001$). Related to height inside the trolley, there were differences between the upper vs. middle height and upper and bottom height (all $P < 0.001$); middle height had the higher T^a

(estimate = $29.97^\circ\text{C} \pm 0.145$) than upper (estimate = $28.66^\circ\text{C} \pm 0.146$) and bottom (estimate = $29.72^\circ\text{C} \pm 0.146$) heights, the difference between mean temperatures varied on average 1.06°C . With regard to positions inside the container, there were differences between central row and lateral rows, the central row was the one that showed a higher T^a (estimate = $29.84^\circ\text{C} \pm 0.133$), whereas the lateral rows showed lower air T^a (estimate = $29.06^\circ\text{C} \pm 0.133$). In the case of zones inside the container, there were different temperatures between zone 1 (near to the cabin) vs. 2 (in the central point) and 1 (near to the cabin) vs. 3 (close to the back doors) (all $P < 0.001$). Zone 1 (near to the cabin) showed the highest mean temperature (estimate = $30.35^\circ\text{C} \pm 0.154$) compared with zones 2 (in the central point) (estimate = $28.95^\circ\text{C} \pm 0.143$) and 3 (close to the back doors) (estimate = $29.05^\circ\text{C} \pm 0.143$); the mean air temperature differences detected between zones inside the container varied more than 1°C , being zone 3 (close to the back doors) the most heterogeneous. The interactions height*position and position*zone were statistically significant ($P < 0.0001$ and $P = 0.0170$; respectively). **Figure 5** shows the temperatures estimate values as per the significant interactions. The interaction position*zone (**Figure 4A**) showed that air temperature in a certain position (row) inside the container was different depending on the zone inside the container, this difference could vary by more than 1°C .

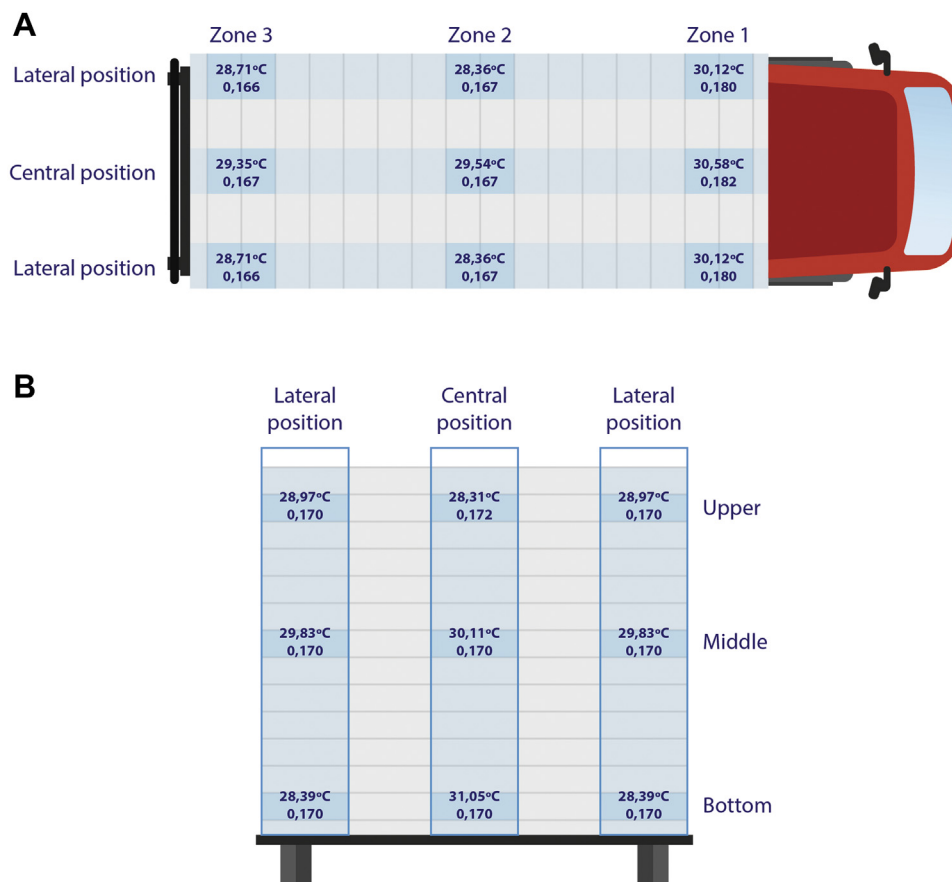


Figure 4. Estimate RH values and SE during day-old chicks transport. Interaction between height and position (back-door view).

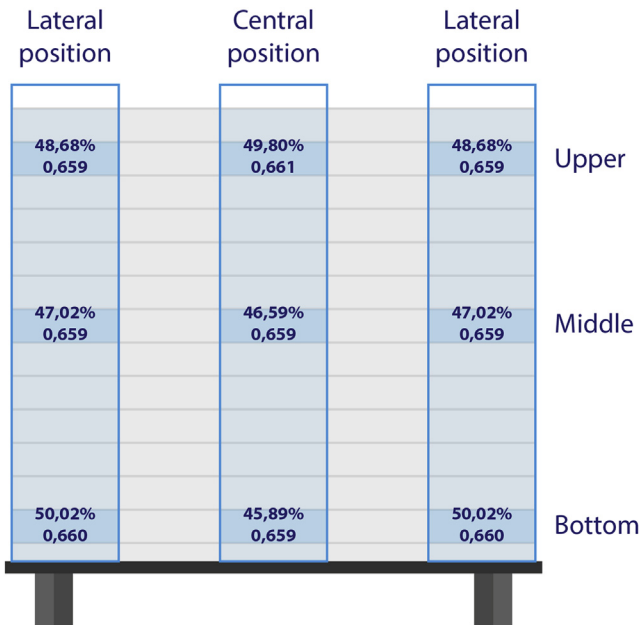


Figure 5. Estimates of the mean temperature values and SE during day-old chicks transport. (A) Interaction between zone and position (air view). (B) Interaction between height and position (back-door view).

In addition, the differences detected in this interaction for upper and bottom height inside the trolley depending on position inside the container were significant ($P = 0.0005$ and $P < 0.0001$; respectively). However, the differences between positions inside the container at middle height inside the trolley were not significant ($P = 0.1348$). The height*position interaction (Figure 4B) showed that the air temperature gradient by heights inside the trolley were more pronounced in the central position (row) than in the lateral positions (rows) inside the container. Moreover, the differences detected in this interaction for zones 1 (near to the cabin), 2 (in the central point), and 3 (close to the back doors) inside the container depending on position inside the container were significant ($P = 0.0263$, $P < 0.0001$ and $P = 0.0005$; respectively).

Finally, no differences in air temperature were detected depending on journey duration (h), type of stop, percentage of day-old chicks load per journey (%), and mo.

DISCUSSION

Phase I

Weight Loss During Transport Weight of chicks is a crucial variable when considering performance of chicks, as it will influence their capacity to grow. However, weight loss might also indicate welfare problems as it can be a consequence of stress during transport (Mitchell 2009; Jacobs et al., 2016). As per our results, weight loss during transport is associated with journey duration and RH, and these results coincide partially with those from Jacobs et al. (2016) and Bergoug et al. (2013). The latter explained that a negative correlation between weight loss and journey duration was

maintained over time, lasting up to day 21 after birth. Jacobs et al. (2016) suggested that any weight reduction after transport is probably because of delayed feed intake, as in their study, the negative effect of transport on the chicks' weight did not persist until slaughter age. The same result was confirmed by other authors (Batal and Parsons, 2002; Bergoug et al., 2013). In fact, Baião et al. (1998) suggested that the negative effect observed on chick weight and subsequent impact at early ages may be more related to a longer interval between hatching and housing than to transport itself. Likely because of this reason, in their study, the weight and feed efficiency at the end of the growth period did not change.

In the case of RH, this environmental variable impacts the capacity for heat exchange (sensible and latent) of broiler chicks (Lin et al., 2005; Schmidt et al., 2009). The loss of evaporative heat increases with temperature but decreases with humidity. When the RH is higher than 60%, heat dissipation is reduced, which harms the reduction of body temperature (Kettlewell et al., 2000; Nazareno et al., 2016). In line also with our results, when chicks are exposed to a heat challenge with high RH, the efficacy of the thermoregulation system may be compromised, and chicks will need to use other pathways to lose heat, accelerating metabolism. When this occurs, part of the energy that should be used to gain weight will be dedicated to thermoregulatory process, reducing performance (Abreu et al., 2017). Lin et al. (2005) suggested that broiler chicks are sensitive to changes in humidity, even when temperatures are thermoneutral, and observed the influence of RH on cloacal and peripheral temperatures. They showed that when temperature and RH are high, the evaporative and non-evaporative heat loss decrease and chicks activate alternative physiological pathways to redistribute heat within the body to adapt to the environment. This, may explain why the higher environmental humidity in high temperatures results in greater weight loss in chicks.

Chick Mortality During Transport and at First Wk of Life

The impact of mortality for the performance and the welfare of any animal production system are unquestionable. As per our results, no effect of transportation was found on mortality during transport, which confirms the findings of other studies (Bergoug et al., 2013; Jacobs et al., 2016). Ritz et al. (2005) emphasized the difficulty in associating mortality during transport with thermal stress or any other transport variable or even with any effect during all the growth period. However, we found that transportation was indeed associated with mortality during the first week of life and more precisely with the percentage of day-old chicks transported per journey. Similarly, Chou et al. (2004) found an association between mortality during the first week of life and transportation distance. However, this association is still controversial as other authors did not find any relationship between the same variables (Bergoug et al., 2013; Jacobs et al., 2016). This difference could be because of the fact that Chou et al. (2004) focused on journey duration without considering other fixed effects related to transport such as

environment conditions during transport or the percentage of chicks transported per journey.

Regarding the percentage of day-old chicks loaded per journey, according to Nazareno et al. (2016), there are 2 environments inside the truck (the container environment and the environment inside transport boxes), with the highest averages for air T^a and RH inside the chick boxes. Considering the existence of these 2 environments that can thwart environmental stability, in addition to the quantity of chicks load per journey, the greater percentage of chicks per journey the higher the divergence between those environments, likely increasing temperature inside the transport boxes. These could lead to thermal heat stress for the chicks, making it more difficult for them to dissipate heat (Ernst et al., 1984; Yalçın et al., 1997). It is well established that heat stress may facilitate dehydration and increase rate mortality in early life (Bergoug et al., 2013; Piestun et al., 2017).

In addition to transport variables, we also found that the first-week mortality differs as per chick gender. Our results are in accordance with those from Leitner et al. (1988), who detected significant differences for mortality between males and females during the first 8 wk of life. They hypothesized that males are more susceptible to pathogens and therefore have a higher mortality. However, infectious diseases were not monitored in the present study, and therefore, we cannot confirm the hypothesis of Leitner et al. (1988).

Phase II

Taking into account that there were transport-related variables affecting the welfare and productivity of broilers, it was considered important to study the performance of environmental variables during transport and the most likely reasons to explain environmental variations inside the trailer.

Microclimate Profile The findings obtained in the microclimate assessment (Table 1) indicate an environmental heterogeneity inside the container and coincide with the studies conducted by Knezacek et al. (2010), Filho et al. (2014), and Nazareno et al. (2015b). Marques (1994) and Quinn and Baker (1997) attributed this heterogeneity to low air circulation, caused by problems in the air-conditioning and ventilation system of trailers, as well as to the nonstandardisation of load density in journeys.

RH and air temperature As shown in phase I, the RH had an effect on weight loss during transport. Humidity affects the animal depending on the environmental temperature. For this reason, the importance of the association between T^a and RH is discussed. It is important to clarify the temperature difference between the integrated probes and the trial probes. In the case of integrated probes, there were only 2 probes installed at the truck's roof with roughly 25 cm between the probe and day-old chicks' trolleys, whereas there were 27 trial probes located next to the chicks' boxes. The localization as well as the number of the trial probes

may have offered a more realistic overview of what is happening inside the truck than the integrated probes. The variability detected in RH and temperature inside the container was in line with other studies. However, there is a lot of variation between authors as regards the thermal and RH range inside the container. Meijerhof (1997) and Weeks and Nicol (2000) suggested a temperature range between 24°C and 26°C, without alluding to RH, whereas Marques (1994) recommended temperatures between 22 and 31°C and a RH of 50%. Finally, Nazareno et al. (2016) found that the temperature and RH means were 28.5°C (23.3°C–32.2°C) and 40.5% (31.4%–54.1%), respectively. This was the study that had the most similar results to our study.

There are several possible reasons for this environmental variability. First, as mentioned earlier, it could be the influence of air circulation added to an inefficient ventilation system, causing a wide range of temperature and RH (12°C and 40%) (Nazareno et al., 2015a), with particularly conflictive hot spots. Quinn and Baker (1997) suggested that the distribution of dead chicks in the truck does not follow a random distribution but reflects the variation in ventilation and areas with critical environmental conditions. The second reason could be heat metabolic production (Yalçın et al., 2001), as it could exacerbate the existing thermal gradient between zones, positions, and heights inside the container. In addition, the combination of the 2 environmental variables (RH and T^a) could compromise transpiration, exacerbated by the imposed high number of birds in a transport container and in the day-old chick boxes (Mitchell and Kettlewell, 1998). The third reason is the existence of 2 environments, one inside the container and the other inside the chick box, the latter having the highest averages for temperature and RH (Nazareno et al., 2016). Therefore, to achieve a comfortable environment for the transport of day-old chicks, the truck design and the air-conditioning system efficiency should facilitate the homogenization of the environment throughout the trailer, avoiding significant fluctuations of humidity and temperature among the containers.

In conclusion, under commercial conditions, transportation of day-old chicks increased weight loss during transport, with journey duration and RH having a negative impact on chicks' BW. No effect of transportation was detected on mortality during transport. However, mortality during first week of life was affected by the percentage of chicks loaded per journey. Variations in RH and air temperature during transport may have a negative effect over welfare and productivity of day-old chicks. To address these, there is an urgent need to refine the air-conditioning and ventilation systems of day-old chick transport to achieve a greater environmental homogeneity in trailer. Improving the control of environmental variables during transport may help to increase environmental homogeneity inside the truck, which this article demonstrates to have beneficial effects for productivity and the welfare of chicks after transport, in the poultry farm.

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