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Reducing pre-slaughter losses of broilers: crating density effects under different lairage periods at slaughterhouse

Redução das perdas pré-abate de frangos de corte: efeito da densidade de aves submetidas aos diferentes tempos de espera no abatedouro

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Abstract The aim of this work was to assess the effects of densities per crate on mortality rates of broilers during pre-slaughter operations, under different lairage time intervals. Pre-slaughter data from 13,937 broiler flocks were recorded daily during 2006, in a commercial slaughterhouse in southeastern Brazil. The main factors which influenced mortality rates were assessed, such as density per crate, daily periods and lairage time in an environmental controlled lairage. For densities above seven birds per crate, an increase in mortality rates was verified mainly in the warm periods. During the night period, the highest incidence of death losses was noticed when the density was below six birds. Considered a controlled environment, the desirable lairage time for death reduction before arrival at the slaughterhouse was above three hours for higher densities and below one hour for densities below seven birds per crate.

Keywords biometeorology, mortality, broiler chicken, pre-slaughter operation, lairage

Resumo O objetivo deste trabalho foi avaliar os efeitos da densidade de aves por caixa na mortalidade de frangos de corte durante as operações pré-abate, em diferentes intervalos de tempo de espera. Dados referentes às operações pré-abate de 13.937 frangos foram registrados diariamente durante 2006, em um abatedouro comercial de frangos de corte no sudeste do Brasil. Os principais fatores que influenciaram a mortalidade dos animais foram avaliados, tais como a densidade de aves por caixa, períodos do dia e tempo de espera em galpão climatizado. Para densidades acima de sete aves por caixa, foi verificado aumento na mortalidade, principalmente durante os períodos mais quentes. Durante a noite, a maior incidência de mortes antes da chegada à linha de abate foi observada quando a densidade esteve abaixo de seis aves por caixa. Considerando um ambiente controlado, o melhor tempo de espera visando redução de perdas por mortalidade antes da chegada ao abatedouro foi abaixo de três horas para densidades elevadas e abaixo de uma hora para densidades abaixo de sete aves por caixa.

Palavras-chave biometeorologia, mortalidade, avicultura de corte, operações pré-abate, espera pré-abate

Introduction

The reducing losses in the broiler industry have been a major concern for the broiler industry. However, limited number of studies regarding the pre-slaughter handling and transport in tropical and subtropical regions have been observed, which, which death losses exceed 1% during warm periods.

During broiler transport, a heterogeneous distribution of temperature and relative humidity within the load it was reported during a broiler transport, due to inadequate

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ventilation. This might result in difference of temperature between "on-board" and outside environment of 3 °C (Mitchell and Kettlewell 1998). However, varying crating density in a transport load may result in thermal stress and high mortality rates on arrival at the slaughterhouse (Nijdam et al 2004; Yalçin et al 2004; Akşit et al 2006). Considering an inefficient process of heat transfer, an increase of cloacal temperature of 1 °C for broilers transported at high crating density was observed (Delezie et al 2007). These findings emphasize the importance of lairage environment handling.

A controlled lairage environment is important for transported broilers to provide good welfare for birds before slaughter (Bayliss and Hinton 1990; Ritz et al 2005). However, conflicting results regarding the best lairage time was observed, varying since below one hour (Hunter 1998; Warriss et al 1999), as well as above two hours (Quinn et al 1998; Silva and Vieira 2010). Additionally, there is little information about the pre-slaughter factors which influence on mortality rates jointly with lairage time in a controlled environment.

Regarding this background, the potential effect of lairage handling under environment control setup on losses reduction during pre-slaughter operations must be considered, mainly for birds transported at high crating density. Therefore, the aim of this study was to assess the effects of densities per crate on pre-slaughter mortality of broilers, under different lairage time intervals.

Materials and Methods

The study was carried out in a commercial slaughterhouse in the State of São Paulo, Brazil (22º01'03''S, 47º53'27''W; 856 m above sea level). From January to December 2006, we recorded the mortality during pre-slaughter time and information related to transport of broilers from farm to the processing plant. Data from 13,937 transport trucks were used.

Pre-slaughter conditions

The processing plant slaughters on average 190,000 broiler chickens per day. The slaughtering started daily at 05:30 h and ended at 03:30 h for cleaning the processing plant. All animals were manually caught by the legs at the farm and were loaded into crates. The crates (0.75 × 0.60 × 0.30 m) were made of plastic material, with perforated walls and floor for ventilation. Each crate had a maximum stocking density of ten chickens (450 cm^2 per bird). After the catching, the birds were transported by road from farm to the processing plant.

At the slaughterhouse, the trucks with broilers were lairaged in an environmentally controlled holding area, which consists of an open building (approximately 23.70 m × 19.22 m × 5 m high), with galvanized steel roof and six metallic trusses. Environment control was achieved by fans mounted on pillars and trusses (four lines of seven fans each), whilst eight high pressure misting sets were intercalated with fans, each one with 25 nozzles. The sides had polypropylene panels during summer, to protect against direct solar radiation inside the building. This building housed eight broiler transport trucks, each one with 486 crates. After the lairage time, birds were commercially slaughtered.

Pre-slaughter assessment

The response variable of this study was the pre-slaughter mortality, for each broiler transport truck. This was the percentage of dead chickens in relation to the total number transported per truck, identified at the point of live hanging from shackles on the slaughter line.

The explanatory factors included in the fitted model were: daily mean dry-bulb temperature and relative humidity, lairage time, daily periods (morning, afternoon and night), density of broilers per crate and seasons of the year (summer, autumn, winter and spring). The lairage time was considered the interval between the arrival of the transport vehicles at the holding area and the unloading of the crates with birds into the unloading bay, categorized as short (less than 1 hour), moderate (1-2 hours), medium (2-3 hours) and high (more than 3 hours), accordingly with Vieira et al. (2010).

Statistical Analysis

The data were analyzed using a Double Generalized Linear Model (DGLM), an extension of Generalized Linear Models (GLM), which provides a framework for modeling the dispersion in generalized linear models as well as the mean. According to Smyth and Verbyla (1999), GLM traditionally considers that the mean μ_i can be modeled by a link-linear relationship (2):

$$g(\mu_i) = x_i^T \beta \qquad (2)$$

where $g(\cdot)$ is a logarithmic function, to make a link between model linear predictor and expected value of preslaughter mortality, treated as a response variable with Poisson distribution. The vector β contains the unknown regression coefficients of the explanatory factors.

Double generalized linear models assume a second link-linear prediction for the dispersion (3):

$$h(\phi_i) = z_i^T \lambda \qquad (3)$$

where h is another known link function and z_i is a vector of covariates affecting the dispersion. Also, the link function

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h(·) was assumed as a logarithmic function, which guarantees positive values for the expected dispersion parameter φ. The Wald statistic was used with the objective of testing the hypothesis about the vector β, that is, to test the true contribution of these factors and interactions on the statistical model (Knight 2000). This test is an extension of the Student's *t* test, commonly used in general linear regression analysis. Complementary to the Wald test, a residual analysis was performed, to verify the model assumptions, based on deviance residuals, fitted values, q-q plots, scale-location plot and Cook's distance, widely used in GLM analysis (McCullagh and Nelder 1998).

For the categorical factors (daily periods and seasons), the dummy coding with three or more levels of categorical variables was used (Table 1). These factors were converted into two or three dichotomous variables, whereas the estimated mean of the third or fourth variable (omitted or reference group) is the intercept term of the model. This explains the absence of the reference group in the fitted model, but implicitly, their underlying effects are jointly adjusted with the others factor levels in the statistical analysis. In this study, the reference group for daily periods was the level *morning* and for seasons, the level *summer*.

The statistical software R (R Development Core Team 2006) was used for estimation, joint to the *dglm* library (Dunn and Smyth 2006).

Table 1 Dummy coding for the categorical variables seasons of the year and daily period

Studied variables	Dummy coded variables				
	Autumn	Spring	Winter	Afternoon	Night
Autumn	1	0	0	-	-
Spring	0	1	0	-	-
Winter	0	0	1	-	-
Summer	0	0	0	-	-
Afternoon	-	-	-	1	0
Night	-	-	-	0	1
Morning	-	-	-	0	0

Results and Discussion

Pre-slaughter assessment

Based on results from DGLM, the following interactions which was significant (p<0.005) were: crating density vs. daily periods; daily mean dry-bulb temperature vs. night and morning; lairage time vs. daily periods; seasons vs. night and morning; external daily mean dry-bulb temperature vs. lairage time; autumn vs. lairage time; crating density vs. lairage time. The influence of these factors was included in the fitted model (mean and dispersion model). In this present study, the interaction between crating density and the factors lairage time and daily periods was discussed.

The following models fitted to assess the number of dead birds per truck, considering the relationship between crating density and the factors lairage time and daily periods were:

$$\hat{y}_1 = \exp(-5{,}01 \cdot 10^{-2\,NS} + 4{,}0 \cdot 10^{-3} e^{*} + 7{,}14 \cdot 10^{-4}\, a^{NS} + 0{,}19\, n^{NS} + 0{,}25\, d^{*} - 5{,}13 \cdot 10^{-4}\, ed^{*} - 7{,}68 \cdot 10^{-2} ad^{*} - 0{,}14 nd^{*}),$$

where $\hat{y}_1$ = average pre-slaughter mortality; e = lairage time; a = afternoon; n = night; d = number of birds per crate (crating density); NS non-significant; * significantly difference (P<0.005), derived by Wald test.

This model showed that crating density had great contribution to the model for mortality estimation in all interactions. This is in accordance with Delezie et al (2007), who reported that the major influence on death losses was the high crating density inside the vehicle, due to high number of birds. Also, interaction between lairage time and crating density was observed, which indicated strong relationship between these explanatory variables which might explain the mortality rates during pre-slaughter operations. According to Warriss et al (1992) and more recently confirmed by Vieira et al (2010), the time factor is important to explain the animal response to prior stress suffered during transport or to a comfort provided by the controlled environment inside the holding area at the slaughterhouse.

To assess the mortality variability, the following dispersion model was fitted:

$$\varphi_1 = \exp(2{,}79^{*} + 34{,}12\, to^{*} + 26{,}15\, to_2 + 9{,}88\, to_3 - 0{,}08\, a^{NS} + 0{,}15\, n^{*} - 1{,}29\, f^{*} - 0{,}56\, i^{*} - 0{,}61{*}p),$$

where to, to_2, to_3 = 3rd degree polynomial factor for daily mean dry-bulb temperature (°C); a = afternoon; n = night; f = autumn; i = winter; p = spring; NS non-significant; * significantly difference (p<0.005), derived by Wald test.

The daily mean dry-bulb temperature and seasons of the year were the variables which had major influence on mortality variability. This evidenced that warm periods and seasons increased the thermal heterogeneity within the vehicle during pre-slaughter operations, with some points with more or less thermal load, affecting the mortality variability throughout the day and year (Baker 1994; Petracci et al 2006; Barbosa Filho et al 2009; Simões et al 2009).

Crating density and daily periods

During the warm daily periods, an increase in mortality rates for birds transported at crating densities above seven birds was observed (Figure 1).

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A slight rise in mortality due to increasing crating density was observed during the morning. However, from the density of seven birds, the increase of dead birds was three animals per truck. At afternoon, no effect was observed on mortality rates between crating densities of five and seven birds. Indeed, an increase of dead birds around 13 birds per truck was observed at the crating density of nine birds. During night time, despite of small reduction in mortality rates with the increase from five to seven birds per crate, no remarkable differences in mortality could be observed in this study.

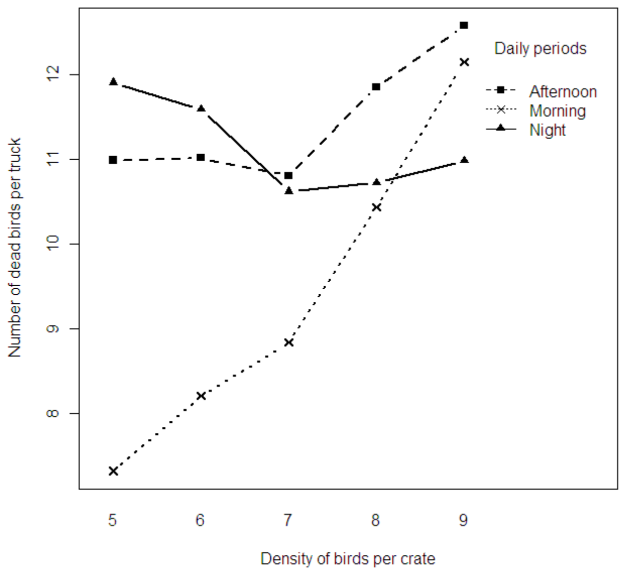

Figure 1 Interaction plot between crating density and daily periods and its effects on pre-slaughter mortality (number of dead birds per truck)

Daily mean dry-bulb temperatures above 22 °C resulted in considerable rising on mortality rates, due to increasing crating density, and are related with temperatures varying between 28 to 32 °C inside crates during warm periods (Barbosa Filho et al 2009). Therefore, a direct relationship between crating density and mortality was noticed, as exposed in this present study during morning and afternoon. High crating densities resulted in an increasing heat production, which reflected in a smaller sensible heat exchange (radiation, conduction and convection). The birds respond by increased panting, which results in addition of moisture inside crates (Nicol and Scott 1990; Simmons et al 1997; Balnave 1998). This difficult to dissipate excess heat through respiratory heat loss in a vapor saturated environment, which results in increasing demands upon their thermoregulatory systems, followed by an increased deep body temperature (Brossi et al 2009). Thus, the mortality rates on arrival were higher in this present study.

Regarding the low variation on mortality rates at night, as noted by Warriss et al (1999), the effect of temperature in seven-week-old broilers submitted to a thermally comfortable environment is practically small or nil. The pre-slaughter factors, including crating density did not alter the thermal conditions of broilers under thermoneutrality (Yalçin et al 2004). In this present study, the mortality rate varied less than 0.3% between crating densities employed at night, evidenced that increasing crating densities during night have lower influence on mortality rates.

The thermal conditions for birds transported at high crating density was critical, based upon the pre-slaughter mortality. Several authors pointed solutions for this problem such as the reduction of crating densities (Nijdam et al 2004; Delezie et al 2007). However, most of the poultry industries have logistics practices which still remaining far from ideal, mainly regarding the choose of welfare-based crating densities for each climatic condition (Silva and Vieira 2010). Therefore, the environmental handling during lairage in an environment controlled holding area showed effective, aiming a reduction in thermal load and consequently the mortality rates of transported birds.

Lairage periods and crating density

Long lairage periods had significant effect ($p<0.005$) on mortality rates (below 0.3%), regarding transported birds at densities above seven birds, as showed in Figure 2. With the reduction of lairage time in this study, the number of dead birds rose until 16 dead birds per truck. However, with reducing crating density, an inverse effect was observed. The shorter lairage time (below one hour), associated with low number of birds per crate (five birds) showed the lower mortality, followed by medium range (two to three hours) and moderate (one to two hours).

Lairage time determines the intensity and effectiveness degree of cooling systems to reduce heat stress of transported bird maintained in a holding area with environment control. The adoption of shorter times do not provides thermal comfort for birds, resulting in weight loss and rising mortality rates (Quinn et al 1998; Akşit et al 2006; Vieira et al 2010).

In other hand, reduced crating densities of birds submitted to an environment controlled lairage during a longer time may result in hypothermia, mainly for birds located in some regions with direct contact with nozzles and fans. This increases the risk of high mortality, either with air temperature above the thermoneutral zone, as evidenced by Hunter et al (1998). In these conditions, the slaughter after the shorter time showed best results when compared with longer lairage times.

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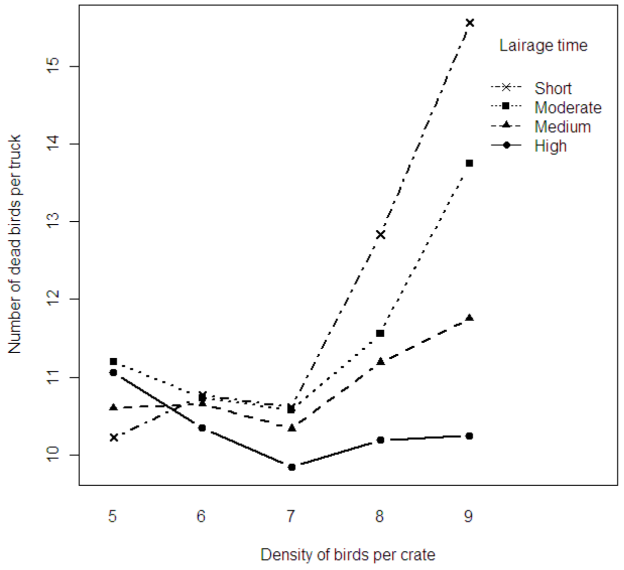

Figure 2 Interaction plot between crating density and lairage times and its effects on pre-slaughter mortality (number of dead birds per truck). Short: below 1 hour; Moderate: 1 to 2 hours; Medium: 2 to 3 hours; High: above 3 hours

Therefore, the employment of intermediate crating density (seven birds) was related with lower mortality rates during all daily periods in this present study (Table 2).

Delezie et al (2007) recommended a desirable area of approximately 576 cm^2 per chicken. Considering the measurements of the crate used for poultry transport in this study (70 x 60 cm), it is equivalent to approximately to seven birds per crate.

Table 2. Recommended values of crating densities for each daily period and its expected mortality rates

Daily period	Crating density	% expected mortality
Morning	7	0.30*
Afternoon	7	0.32*
Night	7	0.31*

*(p<0,005), derived by Wald test.

However, for birds transported at high crating density (above seven birds) and also considering a holding area with environment control, longer lairage times (above three hours) might be enough to provide heat loss of birds after transport (Table 3). For crating densities below seven birds, lower lairage times (below one hour) were best indicated, due to the risk of hypothermia under excessive cooling inside lairage.

Table 3 Recommended values of lairage time related with crating density and its expected mortality rates

Crating density	Lairage times (ranges)	% expected mortality
5 - 6	Short (below 1 hour)	0.41*
7	High (above 3 hours)	0.29*
8 - 9	High (above 3 hours)	0.23*

*(p<0,005), derived by Wald test.

Conclusions

The adoption of lairage times in holding areas with environment control showed efficient on reducing pre-slaughter losses. The desirable crating density based upon the welfare of broiler chickens in transit is seven birds per crate. Aiming thermal comfort for transported birds for different crating densities, lairage times above three hours resulted in lower mortality rates when birds was transported at high crating densities and below one hour for birds transported at lower crating densities. These findings could be applied for further improvement of a logistics programming for pre-slaughter operations of broiler chickens to be reared in tropical and subtropical climate conditions.

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