647. Vieira, F.M.C., Silva, I.J.O., Barbosa Filho, J.A.D., Vieira, A.M.C. and Broom, D.M. 2011. Preslaughter mortality of broilers in relation to lairage and season in a subtropical climate. *Poult. Sci.*, 90, 2127-2133.

Preslaughter mortality of broilers in relation to lairage and season in a subtropical climate

F. M. C. Vieira,*[1] I. J. O. Silva,* J. A. D. Barbosa Filho,† A. M. C. Vieira,‡ and D. M. Broom§

**Animal Environment Research Nucleus, Department of Biosystems Engineering, University of São Paulo, Avenida Pádua Dias, 11, PO Box 9, 13418-900 Piracicaba, Brazil; †Department of Agricultural Engineering, Federal University of Ceará, 60450-760 Fortaleza, Brazil; ‡Department of Statistics, University of Brasília, 70910-900 Brasília, Brazil; and §Centre for Animal Welfare and Anthrozoology, Department of Veterinary Medicine, University of Cambridge, Madingley Road, Cambridge CB3 0ES, United Kingdom*

ABSTRACT The preslaughter handling and transport of broilers are stressful operations that might affect welfare and meat quality and could increase numbers of deaths before slaughter. However, the influence of thermal factors during transportation and lairage at slaughterhouses is complex in subtropical regions, where increasing temperature and high RH are the major concerns regarding animal survival before slaughter. In this study we assessed the influence of a controlled lairage environment on preslaughter mortality rates of broiler chickens that were transported during different seasons of the year and had varying lairage times in the subtropical climate. Preslaughter data from 13,937 broiler flocks were recorded daily during 2006 in a commercial slaughterhouse in southeastern Brazil. The main factors that influenced daily mortality rate were mean dry bulb temperature and RH, lairage time, daily periods, density of broilers per crate, season of the year, stocking density per lorry, transport time, and distance between farms and slaughterhouse. A holding area at the slaughterhouse with environmental control was assessed. Using a double GLM for mean and dispersion modeling, the seasons were found to have significant effects ($P < 0.05$) on average mortality rates. The highest incidence was observed in summer (0.42%), followed by spring (0.39%), winter (0.28%), and autumn (0.23%). A decrease of preslaughter mortality of broilers during summer ($P < 0.05$) was observed when the lairage time was increased, mainly after 1 h of exposure to a controlled environment. Thus, lairage for 3 to 4 h in a controlled lairage environment during the summer and spring is necessary to reduce the thermal load of broiler chickens.

Key words: animal welfare, mortality, broiler chicken, preslaughter operation, lairage

2011 Poultry Science 90:2127–2133
doi:10.3382/ps.2010-01170

INTRODUCTION

The high incidence of injuries and thermoregulatory problems during transport is associated with poor welfare and represents a considerable loss to the broiler industry, especially in the tropics. Broilers have limited ability to cope with heat stress, resulting in mortality rates that exceed 1% during the hottest days (Ritz et al., 2005).

Mortality rates vary with season of the year. Petracci et al. (2006) reported higher mortality during summer (0.47%) compared with other seasons. During spring and autumn, thermal stress depends on thermal fluctuations (Nääs et al., 2001). Even during cold days, a heterogeneous distribution of temperature and humidity occurs within the load and, thus, a thermal core inside the lorry might increase death losses in winter (Mitchell and Kettlewell, 1998; Barbosa Filho et al., 2009; Simões et al., 2009).

Lairage time can be 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. To improve broiler welfare and reduce thermal stress after broiler transportation, holding areas with environmental control at the processing plants associated with a suitable lairage time interval can permit distribution of cooled air inside the crates before arrival at the slaughter line (Quinn et al., 1998). Several authors have recommended short lairage times (less than 2 h) because of low energy availability in fasted, metabolically active birds (Hunter et al., 1998; Warriss et al., 1999; Nijdam et al., 2004). Bianchi et

©2011 Poultry Science Association Inc.
Received October 4, 2010.
Accepted June 18, 2011.
[1]Corresponding author: fredvzoo@gmail.com

al. (2005) found no significant effect of lairage time on mortality rate and suggested a controlled fasting time preslaughter to reduce deaths before slaughter. However, the effect of exposing broiler chickens to different lairage times under improved environmental conditions throughout the year has not been studied in tropical and subtropical regions. The aim of this work was to assess the influence of a controlled lairage environment on preslaughter mortality rates of broiler chickens transported during different seasons of the year and subjected to varying lairage times in the subtropical climate.

MATERIALS AND METHODS

This study was carried out in a commercial slaughterhouse in the State of São Paulo, Brazil (22°01′03″S, 47°53′27″W; 856 m above sea level). From January to December 2006, we recorded the mortality during preslaughter time and information related to transport of broilers from farm to the processing plant. Data from 13,937 transport vehicles were used.

Preslaughter Conditions

The processing plant slaughters on average 190,000 broiler chickens per day. The slaughtering started daily at 0530 h and ended at 0330 h so that the processing plant could be cleaned. 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 and had perforated walls and floor for ventilation. Each crate had a maximum stocking density of 10 chickens (450 cm^2/bird). After being caught, 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 that consisted of an open building (approximately 23.70 m × 19.22 m, 5 m high) with galvanized steel roof and 6 metallic trusses (Figure 1). Environmental climatization was achieved by fans (air flow of 300 m^3/min at free air) mounted on pillars and trusses (4 lines of 7 fans each). Eight high pressure misting sets (flow rate of 80–95 mL/min at1,034.21 kPa) were interspersed with fans, each with 25 nozzles. The sides of the holding area had polypropylene panels during summer to protect against direct solar radiation inside the building. This building housed 8 poultry transport trucks, each with 486 crates. Each truck had a maximum stocking density of 4,860 birds.

The birds were slaughtered after data collection. Before the chickens were caught and crated, feed and water were withdrawn for a period of 8 h, which included all preslaughter operations (catching, crating, transport, and lairage at the slaughterhouse).

Preslaughter Assessment

The preslaughter information was recorded by the preslaughter staff throughout the 4 seasons in 2006 (summer: January to March; autumn: March to June; winter: June to September; spring: September to December) and stored in the database of the industry. This database was assessed after slaughtering, aiming to evaluate the data quality control. Outliers were removed before the data analysis.

For each broiler flock, the following data were recorded: stocking density per lorry (number of birds/lorry), density per crate (number of birds/crate), preslaughter mortality (%), and lairage time (h). Transport time (h) and distance between farms and slaughterhouse (km) were not measured and controlled for each flock in the industry. 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.

Environment Characterization

To characterize the environmental conditions during the transport of broiler chickens throughout the study, meteorological data were provided by the weather station of Brazilian Agricultural Research Corporation (EMBRAPA Cattle–Southeast), located in the city of São Carlos, State of São Paulo, Brazil, close to the study slaughterhouse. The climate is humid subtropical according to Köppen (1936), characterized by a warm and wet season from October to March (mean temperature >22°C) and a dry season from June to August (average temperature ∼18°C; Pereira et al., 2002).

To assess discomfort conditions for broilers, the psychrometric measure enthalpy (h) was used as a thermal index. This expresses the thermal energy amount per unit mass of dry air, as described by Rodrigues et al. (2011).

Figure 1. The holding area with environment control at the slaughterhouse.

Table 1. Descriptive statistics of preslaughter characteristics of the studied data set

Preslaughter factor	Mean	SD	Minimum	Median	Maximum
Stocking density/lorry	3,337	467.5	1,944	3,402	4,860
Density of birds/crate	7	0.9	4	7	10
Lairage time (h:min)	02:58	01:37	00:00	02:47	17:38
Transport time (h:min)	01:30	00:58	00:20	01:41	04:00
Transport distance (km)	120	68.4	24	118	242
Preslaughter mortality (%)	0.33	0.87	0.00	0.23	10.88

Statistical Analysis

The statistical design was based on an observational study in which the studied characteristics were obtained from a database offered by the industry. The statistical analysis was performed to test the effect of the seasons and lairage time in a controlled lairage environment on mortality, also considering the other underlying factors that had great influence on the preslaughter mortality as effects in the fitted model. The response variable of this study was the preslaughter mortality for each broiler transport truck. The explanatory factors included in the fitted model were daily mean dry bulb temperature and RH, lairage time, daily periods (morning, afternoon, and night), density of broilers per crate, and season of the year (summer, autumn, winter, and spring).

For an overall descriptive statistics analysis, values of mean, standard deviation, and coefficient of variation of daily dry bulb temperature (°C), RH (%), and air enthalpy (kJ/kg of dry air) were used and recorded 3 times/d (morning, afternoon, and night). The data were analyzed using a double GLM, an extension of GLM, which provides a framework for modeling the dispersion in generalized linear models as well as the mean. This approach may be used in experimental data in which proportions show large variability that exceeds the limit of the theoretical variance of binomial or Poisson distribution. This problem is known as overdispertion, and the double GLM allows the joint modeling ideas for mean and dispersion (Vieira et al., 2010). Also, the double generalized linear modeling identifies which studied factors are associated with the excessive variability. Thus, if any factor might be controlled, it is possible to reduce the mortality variability. According to Smyth and Verbyla (1999), GLM traditionally considers that the mean μ_i can be modeled by a link-linear relationship [1]:

$$g(\mu_i) = \mathbf{x}_\mathbf{i}^\mathbf{T}\boldsymbol{\beta}, \qquad [1]$$

where $g(\ )$ 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, and $\mathbf{x}_\mathbf{i}^\mathbf{T}$ is the vector of covariates of the mean model. The vector $\boldsymbol{\beta}$ contains the unknown regression coefficients of the explanatory factors.

Double generalized linear models assume a second link-linear prediction for the dispersion [2]:

$$h(\varphi_i) = \mathbf{z}_\mathbf{i}^\mathbf{T}\boldsymbol{\lambda},$$

where h is another known link function, $\mathbf{z}_\mathbf{i}^\mathbf{T}$ is a vector of covariates affecting the dispersion, and $\boldsymbol{\lambda}$ is a vector of unknown parameters of the dispersion model. Also, the link function $h(\ )$ 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 $\boldsymbol{\beta}$, 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, 1989).

For the categorical factors (daily periods and seasons), the dummy coding with 3 or more levels of categorical variables was used. These factors were converted into 2 or 3 dichotomous variables, whereas the estimated mean of the third or fourth variable (omitted or reference group) is the intercept term of the model.

Table 2. Summary statistics of lairage time (h) throughout the seasons of the year

Season	Mean	SD	Minimum	Median	Maximum
Summer	03:07	01:48	00:02	02:52	13:53
Autumn	02:59	01:35	00:01	02:49	13:31
Spring	02:55	01:34	00:01	02:44	17:38
Winter	02:55	01:39	00:00	02:45	16:54

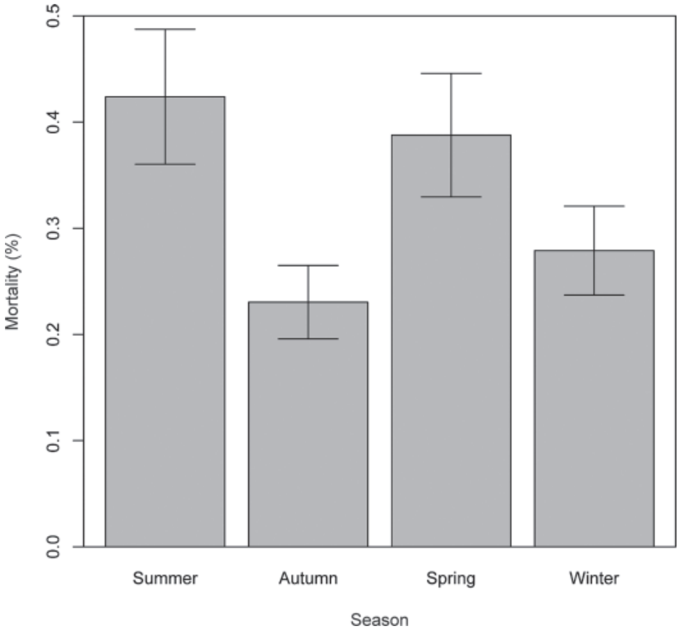

Figure 2. Average preslaughter mortality (%/truck) of broiler chickens during the seasons of the year. Bars show a 95% CI.

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, along with the dglm library (Dunn and Smyth, 2006).

RESULTS

Preslaughter Assessment

The summary statistics of the 13,937 broiler flocks are given in the Table 1. The transport time was at an acceptable level (<4 h) and the mean distance between farms and slaughterhouse was 120 km (the median being close to this), indicating that the farms were located relatively close to the slaughterhouse. Journey time was constant during the year.

The density per crate varied around 7 birds, with a maximum of 10 birds/crate. The stocking density per lorry followed the same trend of the density per crate, with a mean of 3,337 birds. However, a high variability was observed in this variable, indicating that the total number of birds in a flock is heterogeneous. The average lairage time varied considerably during 2006, with a minimum value of 0 and a maximum of 17 h 38 min. The preslaughter mortality minima and maxima were 0 and 10.88%. This finding indicated a possible influence of lairage time on mortality.

The distribution of lairage time for each season is shown in Table 2. The time intervals adopted during the year were very similar between the seasons, with a slight increase during the summer given the high temperature during December to March, during which environmental control was increased. Autumn, spring, and winter had similar variations in lairage time, whereas in spring the maximum value was 17:38 h.

Environmental Characterization

Environmental data description among the seasons is shown in Table 3. As expected, average temperatures were higher in summer and spring. However, the highest coefficient of variation for temperature, RH, and enthalpy was recorded in winter. The considerable variation during autumn and winter can be explained by the increased incidence of heat waves followed or preceded by cold days in a short time interval. The RH was higher in summer and spring than in other seasons because of the high amount of rainfall during this period.

Based on enthalpy, the highest incidence of heat stress for broiler flocks was observed during the summer, followed by spring, as expected, because of the joint effect of high temperature with high values of RH. During the winter, the broilers were transported under comfortable conditions, indicated by the lowest amount of thermal energy in dry air (44.2 kJ/kg). Autumn provided the second best conditions (51.6 kJ/kg).

Effect of Season

The distribution of preslaughter mortality during the seasons is shown in Figure 2. The average percentage of birds dead on arrival at the slaughterhouse was higher in summer (0.42%) and spring (0.39%) than in winter (0.28%) and autumn (0.23%). Considering that the animals were transported under harsh environmental conditions during summer and spring, as shown by enthalpy values, this result was expected given that the

Table 3. Mean (SD) and CV of environmental conditions throughout the study

	Dry bulb temperature		RH		Air enthalpy	
Season	°C	CV (%)	%	CV (%)	kJ/kg of dry air	CV (%)
Summer	22.9 (3.0)	13	83 (12)	14	62.9 (5.3)	9
Autumn	19.8 (4.1)	21	80 (14)	18	51.6 (9.8)	18
Winter	18.8 (4.8)	26	68 (19)	28	44.2 (8.1)	18
Spring	21.7 (3.4)	15	82 (13)	16	58.4 (7.7)	14

Table 4. Double GLM for mortality (no. of dead birds/truck) estimation [mean model with the effects of lairage time (min) and season of the year]

Factor	Estimate	SE	*P*-value
Intercept	5.009×10^{-2}	0.285	0.860
Lairage time	3.996×10^{-3}	1.099×10^{-3}	<0.0001
Autumn	−0.714	6.567×10^{-2}	<0.0001
Winter	−0.493	7.333×10^{-2}	<0.0001
Spring	−0.258	6.294×10^{-2}	<0.0001
Lairage time vs. autumn	1.036×10^{-3}	2.883×10^{-4}	<0.0001
Lairage time vs. winter	2.859×10^{-4}	3.193×10^{-4}	0.371
Lairage time vs. spring	4.396×10^{-4}	2.680×10^{-4}	0.101

effects of high temperature and RH are more harmful for welfare and mortality rates of broilers.

Lairage Time and Season

The interactions between the variables for which $P < 0.05$ in the mean model were temperature, lairage time, daily periods, density of birds per crate, and season. No interactions were observed specifically between temperature and afternoon, lairage time and winter, lairage time and spring, and afternoon and all seasons ($P > 0.05$). The effects of these significant factors were considered in the model (mean or dispersion model). In this study, the following results and discussion are focused on the contribution of the lairage time in a controlled lairage environment, jointly with the seasons of the year in preslaughter mortality, as given in Table 4. The interaction between seasons and lairage time had a positive effect on mortality. However, the contribution of each season to explain the mortality was stated in the model ($P < 0.05$) despite the lack of interactions between spring and winter with lairage time.

Regarding the dispersion model, the seasons of the year contributed linearly and negatively to the increase of mortality variability (Table 5). This indicates that the transport during these seasons resulted in lower variability. As expected, the temperature had expressive and positive contribution to the mortality variability. Also, the dispersion model showed that broiler transport in the afternoon reduced 0.085 U of the mortality variability, whereas transport at night resulted in an increase of 0.145 U of mortality variability. This was expected because the preslaughter conditions (mainly the thermal influence) were more variable during the night than during afternoon and morning. During the night, stressful and comfortable conditions were observed throughout the year; this characterizes a high variability for this period. The afternoon is generally most severe for broiler welfare and the variability of these conditions is low given the lack of numerous comfortable observations during the year.

The relationship between season and lairage time in a controlled environment and the effects on mortality are shown in Figure 3. During the winter, the preslaughter mortality was not affected by lairage time ($P > 0.05$) as much as during the autumn. The number of dead broilers per lorry was greater during the summer and the spring. However, longer lairage times at an environmentally controlled holding area resulted in a lower number of dead broilers before slaughter during these hottest seasons. Above 1 h of lairage in a controlled lairage environment, the reduction was more effective during the summer and a greater reduction in mortality was observed compared with other seasons. This

Table 5. Double GLM for mortality (no. of dead birds/truck) estimation (dispersion model)

Factor[1]	Estimate	SE	*P*-value
Intercept	2.791	0.033	<0.0001
poly(temp)1	34.116	2.452	<0.0001
poly(temp)2	26.154	1.559	<0.0001
poly(temp)3	9.876	1.471	<0.0001
Afternoon	−0.085	0.043	5.011×10^{-2}
Night	0.145	0.031	<0.0001
Autumn	−1.290	0.040	<0.0001
Winter	−0.558	0.039	<0.0001
Spring	−0.612	0.034	<0.0001

[1]poly(temp)1,2,3 = 3rd degree polynomial factor for air temperature (°C) taken from the nearby weather station.

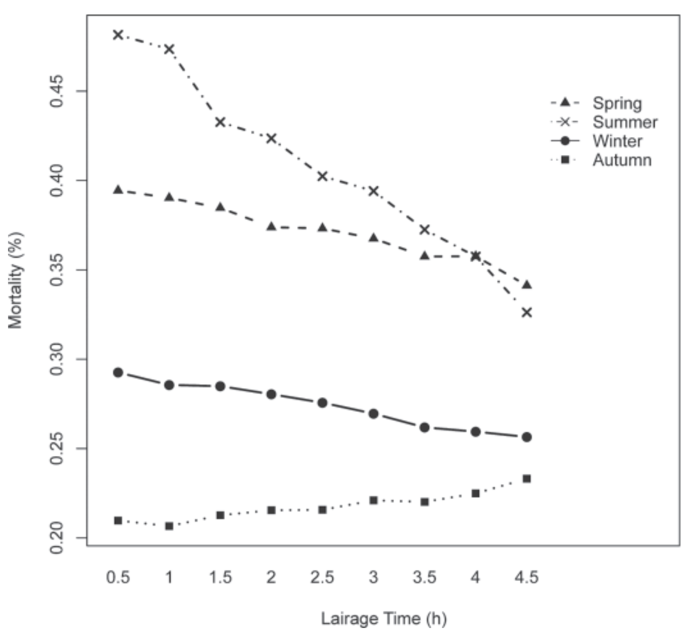

Figure 3. Interaction plot between lairage time intervals (h) in a controlled lairage environment and season of the year and its effects on preslaughter mortality (%/truck) of broiler chickens.

reduction, attributable to an increasing lairage time in a controlled lairage environment, suggests the practical importance of this approach.

DISCUSSION

During the summer and spring of 2006, high mortality rates were expected given the high sensitivity of the broiler genotypes to increased temperature and RH (Nijdam et al., 2004; Vecerek et al., 2006; Gregory, 2009). In agreement with this expectation, Petracci et al. (2006) reported an increase of 43% in mortality of poultry transported during the summer (0.47%) compared with other seasons. According to these authors, the temperature and RH were about 23°C and 77%, respectively. In this study, during the summer and spring the average RH in the transport environment was 83 and 82%, respectively, indicating a heat stress scenario for broilers corresponding with mortality of 0.42 and 0.39%, respectively.

With regard to the effect of different lairage times in a controlled environment, these results confirmed that thermal treatment during the lairage at slaughterhouses can affect mortality rates in different seasons (Bayliss and Hinton, 1990; Bressan and Beraquet, 2002; Bianchi et al., 2005; Barbosa Filho, 2008). However, a reduction in preslaughter mortality as lairage time in a controlled lairage environment increased during summer was contrary to previous reports (Hunter et al., 1998; Warriss et al., 1999; Nijdam et al., 2004). It seems likely that increased environmental control in the holding area during summer and perhaps fasting time might be the reason for differences between previous studies and the present study.

The previous trials concerning thermal environment during broiler preslaughter operations were conducted in a temperate climate, whereas this study was conducted in a subtropical region. However, a large difference between temperate and tropical climates for broilers was reported because of high temperature in the tropics (Yalçin et al., 1997; Gowe and Fairfull, 2008). Therefore, a controlled environment is essential to improve the heat dissipation rate of broilers subjected to hot and humid conditions (Simmons et al., 2003).

Regarding the environment control in holding area, Hunter et al. (1998) studied a holding area with passive ventilation without water misting in the United Kingdom. The birds were subjected to 4 h of lairage and the temperature inside crates increased approximately 10°C over a 2-h period. Bayliss and Hinton (1990), in the same location but studying a different holding area layout, reported lower mortality rates of broilers (0.2%) in an environmentally controlled holding area with forced ventilation and water misting during summer. The results of the present study were in agreement with that study. When the lairage time was greater than 1 h, under controlled environment, a lower mortality rate (approximately 0.35%) was observed.

One of the major arguments against lairage time is the fasting time and energy depletion during preslaughter operations. Concerning this point, Warriss et al. (1999) and Nijdam et al. (2004) considered that the high mortality during transport and lairage was attributable to feed and water withdrawal, which causes metabolic exhaustion and, consequently, increased mortality rates. However, in the present study, the total feed withdrawal period included all preslaughter operations (catching, loading, transport, and lairage at slaughterhouse) for birds transported during 2006, contrary to prior studies. In other words, all broilers experienced the same amount of time of feed withholding. This logistic control might reduce the variability of the operation time and the preslaughter losses. Also, with the environmental control in the tropical regions, this practice allows improvement of broiler welfare during lairage and reduced mortality. This is in accordance with Bianchi et al. (2005), who reported that lairage time did not affect mortality rate because of environmental control of the holding area and concluded that a correct planning of feed withdrawal (taking into account the time birds spend fasting on the farm, in transit, and in lairage at the processing plant) is necessary to reduce the risk of death before slaughter. Moreover, Ritz et al. (2005) and Nääs et al. (1998) showed that the environmental temperature with distribution of cooled air into the crates had great influence on mortality at the stage of lairage. This is only possible with a waiting time that allows the birds to return to thermal balance and therefore enhance survival.

Differences in mortality between winter and autumn were not observed in this study. During the winter, lairage time in a controlled environment did not show any effect on mortality rates ($P > 0.05$). This could be explained by the thermal profile during these seasons, classified as comfort in most months. According to Bressan and Beraquet (2002), in days of thermal comfort, the lairage time with a controlled environment can either be kept short or excluded from the process, if possible. The effect of temperature below 17°C on mortality rates was nil or very small, not exceeding 0.13% of dead birds before arrival (Warriss et al., 2005). Similar results were found in the present study, in which average preslaughter mortality registered during winter and autumn was 0.28 and 0.23%, respectively.

We conclude from the current study that the increase of lairage time in an environmentally controlled holding area reduced the mortality rate of broilers transported in the hottest seasons of the year in the subtropical climate. A lower mortality rate was observed in broiler flocks exposed to a controlled lairage environment for 3 to 4 h in summer and spring, and in flocks maintained for 1 h of lairage in winter and autumn, under the same environment control at the holding area. Therefore, the controlled lairage environment could be implemented during hot periods, regardless of season, to improve welfare and reduce mortality.

ACKNOWLEDGMENTS

This study was supported by funds provided by the São Paulo Research Foundation (FAPESP; São Paulo, State of São Paulo, Brazil). Thanks to EMBRAPA Cattle–Southeast (São Carlos, State of São Paulo, Brazil), especially Odo Primavesi, for allowing the access to the meteorological data.

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