Production Losses on Poultry Pre-Slaughter Operations in Relation to Density per Cage: A Daily Period Effects Study

F. M. C. Vieira[1*], I. J. O. Silva[1], J. A. D. Barbosa Filho[1], A. M. C. Vieira[2], D. B. Garcia[1], and A. Hildebrand[1]

[1] Animal Environment Research Nucleus, University of São Paulo, Piracicaba-SP-Brazil

[2] Department of Statistics, University of Brasilia, Brazil

* Corresponding author: E-mail: fmvieira@esalq.usp.br

Abstract. *Advances in world poultry production in recent years have driven discussion about the critical points during the productive process that increase losses, with emphasis on poultry mortality. Although research has been conducted towards the raising environment, a lack of studies exists on the pre-slaughter operations, which are the largest sources of losses before arrival at a slaughter plant. Thus, the present study aims to evaluate the effect of the number of birds per cage on the mortality rates, considering time of day. This trial was conducted in a commercial abattoir in the State of Sao Paulo, Brazil, in 2006. The historical data set from more than 13,000 trucks, about broilers mortality during pre-slaughter operations, was achieved through the abattoir. Factors that influence the welfare of the birds were collected, such as the daily thermal condition and the number of birds per cage. Statistical analysis was performed using the Double Generalized Linear Models. As results, there was a sharp reduction in mortality during the night with 7 birds per cage, from which the increase was mild. This similar behavior was recorded during the afternoon, with the lowest mortality associated with the density of 7 birds. During the morning, the increase in mortality occurred up to 5 birds per cage, up to the peak of 9 birds. Therefore, these results suggested an adoption of approximately 7 birds per cage, mainly in the afternoon and night, to reduce the mortality rates.*

Keywords. *Mortalities, Lairage time, Broilers, Abattoir, Temperature, Welfare*

Introduction

Nowadays, reducing poultry losses is the major challenge for which the whole poultry industry should direct practical solutions. A little information is known about the location of these losses in broiler chicken production. Even less is known about the quantification of losses in each critical point “after farm”.

Researches have produced important information to improve of the pre-slaughter operations. Nijdam et al. (2004) observed that the increase of the bird density per cage resulted in increases in relative humidity, which difficult the thermal changes between birds and the environment where they are held. Delezie et al. (2007) discussed that the variation of the density of birds per cage during hot and cold days causes thermal stress of the birds, finding ideal densities between 7 and 8 birds per cage. Concerning the periods which birds are transported, previous research showed that the greatest losses occur during hot periods, but losses are alerting for the nocturnal period, due to the drop in temperature and the increase in relative humidity, considering that there is a thermal gradient between the load and external environment (Bayliss & Hinton, 1990; Nicol & Scott, 1990; Yahav et al., 1995; Mitchell & Kettlewell, 1998; Nijdam et al., 2004; Yahav et al., 2005).

However, the responsible factors for the pre-slaughter operation losses should be assessed in a joint analysis, since the losses are not singly influenced for each one. Thus, the summary of some variables generates information that can help correct the decision-making process regarding the changes on pre-slaughter operations. Moreover, few works evaluated the effect of weather and other factors related to losses in tropical conditions, due to most research being carried out in temperate regions. Relating the change over the months and daily periods with the DOA, historical assessments, such as those of Bayliss and Hinton (1990), Petracci et al. (2006) and Vecerek et al. (2006), have not been made in Brazil, considering the actual thermal variability.

Many studies have been conducted in countries with temperate climate, detailing each one of the pre-slaughter transactions, and examining the effects of other factors that influence losses. However, such research has not covered joint analyses of the factors and few studies have been conducted in tropical regions. Considering the climate change scenarios that alter strongly the distribution of heat throughout the year, livestock production is included in this context, holding all production systems of risk concerning the change in productivity based on thermal comfort animal, because the birds are very sensitive about the environment where they are held. Thus, the present study aims to evaluate the effect of the daily thermal condition with the number of birds per cage on the mortality rates.

Material and Methods

The trial was conducted in a commercial poultry processing plant, located in the State of Sao Paulo, Brazil. For this study, a data set about the pre-slaughter operations in 2006 was used. Data from 13,937 vehicles were studied, involving the following variables: density per cage, lairage time (lower than 1 hour, 1-2 hours, 2-3 hours and upper than 3 hours), seasons of the year (summer, autumn, winter, spring) and the daily variability (morning, afternoon and evening) of the main factors (Figure 1). Dry bulb temperature (DBT, °C) and relative humidity (RH, %) was obtained from a weather station in the city, from January to December 2006. The stocking density per cage considered in this trial was the number of birds transported in each transport module.

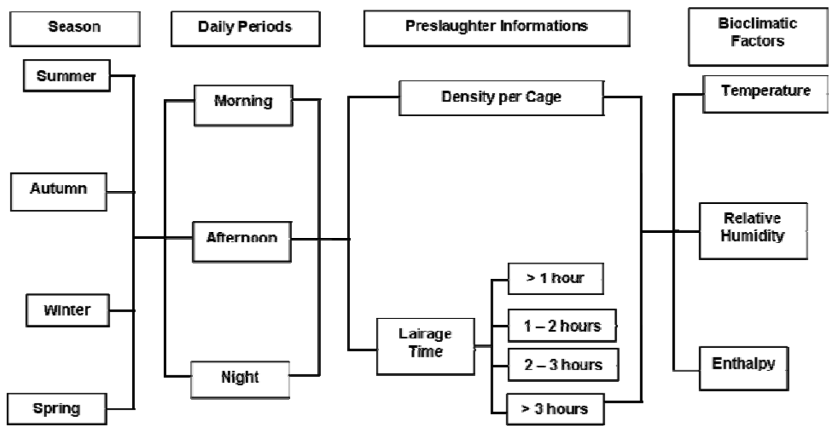

Figure 1. Flowchart of variables involved in pre-slaughter operations.

This bioclimatological analysis was based on days of thermal comfort and stress, using the psychrometric variable enthalpy (H), like as a thermal comfort index, which express the thermal energy contained in 1 kg of dry air, through empirical equation (1), given by Villa Nova (personal communication), cited by Barbosa Filho (2005):

$$H = 6{,}7 + 0{,}243 * T + \left\{ \frac{UR}{100} * 10^{\left(7{,}5*T / 237{,}7*T \right)} \right\} \quad (1)$$

where H: enthalpy (kJ/kg dry air); T: dry bulb temperature (°C); and UR: relative humidity (%).

For a practical understanding of the data, the classification of the poultry thermal condition through enthalpy given by Barbosa Filho et al. (2007), which comprises 4 ranges of comfort and heat stress: comfort 54.7 – 62.9 kJ/kg dry air; alert: 63 – 68.6; critic: 68.7 – 75.8; and lethal: above 75.9 kJ/kg of dry air.

The productive loss variable used in this work was the death on arrival at the abattoir (DOA), obtained by the slaughterhouse data set.

The experimental design used was non-structured, explained by the observational study type, without disturbance in daily processing plant work. The statistical analysis approach used was a Double Generalized Linear Model, as proposed by Smyth and Verbyla (1999), an extension of Generalized Linear Models (GLM), which provides a framework for modeling the data mean and dispersion simultaneously. DOA´s were treated as a response variable with Poisson distribution. The Logarithmic function was assumed to make a link between the linear model predictor and the expected value of the response variable. The Wald statistic was used to test the hypothesis about β parameters, that is, to test the true contribution of these factors on the statistical model. This test uses general inference of the t-Student's test, widely used in GLM analysis. This analysis was processed using the statistical software R (R Development Core Team, 2006).

Results and Discussion

Regarding the annual variability in temperature throughout the day (Figure 2), at night there was an average dry-bulb temperature of 18.1 °C, with a standard deviation of 3 °C. However, the variations were between a maximum and minimum of 9 °C and 25 °C, approximately. In the morning, the average was 20.3 °C, also with a standard deviation of 3 °C. The maximum and minimum during this period were 11 ºC and 27 °C, respectively. In the afternoon, the average recorded was 25.2 °C and standard deviation of 3 °C, with maximum and minimum values of 18 and 33 ° C, approximately.

At night, the average humidity recorded was 86% with a standard deviation of 10%. Similar values were found on morning, with an average of 80% and a standard deviation of 11% and during the afternoon, the average recorded was 63% with a standard deviation of 17%. Regarding desirable temperature and humidity values for broiler chickens, proposed by several authors (Milligan & Winn, 1964; Adams & Rogler, 1968; Curtis, 1983; Silva, 2000; Macari & Furlan, 2001), the animals were in heat stress conditions just on a few days throughout the afternoon, considering both the temperature and relative humidity. In the morning, concerning temperature values, the whole days were found within the range comfort, but it was not verified in relation to the relative humidity, because some days exceeded this limit. During the night, the chickens were in the cold stress range during a few days, increased by high humidity in most of the year.

Regarding the enthalpy, the presented results confirm the relationships discussed above, between the temperature and humidity, within each daily period (Figure 1). The afternoon showed alert ranges, above of 63 kJ / kg dry air. That is, 50% of the frequencies were found in the critical range, coming to the lethal range in extreme situations. In the morning, the birds were transported in the comfort and alert, between 57 and 66 kJ / kg dry air. During the night, the enthalpy remained in the range of comfort, between 54 to 62 kJ / kg dry air, with some observations in the alert range. Both the night and the morning showed a few days below the zone of thermal comfort, indicating that the birds may have suffered cold stress.

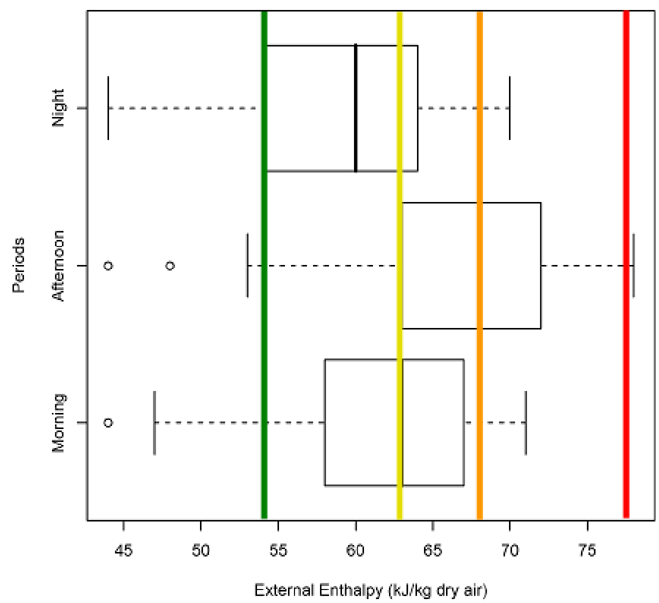

Figure 2. External enthalpy profile in relation to daily periods in 2006 and the enthalpy ranges: Comfort (green line): 54.7 – 62.9 kJ/kg dry air; Alert (yellow line): 63 – 68.6; Critic (orange line): 68.7 – 75.8; Lethal (red line): 75.9.

As results of the statistical analysis, a double generalized linear model was adjusted, after the mean and dispersion model adjusting, as indicated in Table 1, for mean adjusting:

Table 1. Double generalized linear models for predicting poultry losses based upon daily periods, density per cage, and temperature.

Interactions	Model[y]	Significance
No. of birds per cage x Period (Night)	$\hat{y} = \exp\{-5.01 \cdot 10^{-2} + 0.19\ n + 0.25\ d - 0.14\ nd\}$	*
No. of birds per cage x Period (Afternoon)	$\hat{y} = \exp\{-5.01 \cdot 10^{-2} + 7.14 \cdot 10^{-4}\ a + 0.25\ d - 7.68 \cdot 10^{-2}\ ad\}$	*
Temperature x Period (Night)	$\hat{y} = \exp\{-5.01 \cdot 10^{-2} + 0.19\ n + 3.25 \cdot 10^{-2}\ t + 3.28 \cdot 10^{-2}\ nt\}$	*
Temperature x Period (Afternoon)	$\hat{y} = \exp\{-5.01 \cdot 10^{-2} + 7.14 \cdot 10^{-4}\ a + 3.25 \cdot 10^{-2}\ t + 1.90 \cdot 10^{-2}\ at\}$	NS

$\hat{y}$ = expected number of dead broilers; n= night; d= density per cage; a = afternoon and t = temperature.
NS Non-significant.
* Significant difference (P<0.005), derived by Wald Test.

Analyzing the data relating to the nocturnal period (Figure 3), there was a change in the mortality of animals in different ranges of density. A limit between 3 to 7 birds per cage was observed, which mortality rate was reduced to the minimum mortality in the densities of 7 birds. But above 8 birds per cage, a smooth increase in the number of dead birds was observed. Furthermore, with a small number of birds per cage, in the density of 3 birds, there was an increase in the maximum mortality of approximately 13 birds by load.

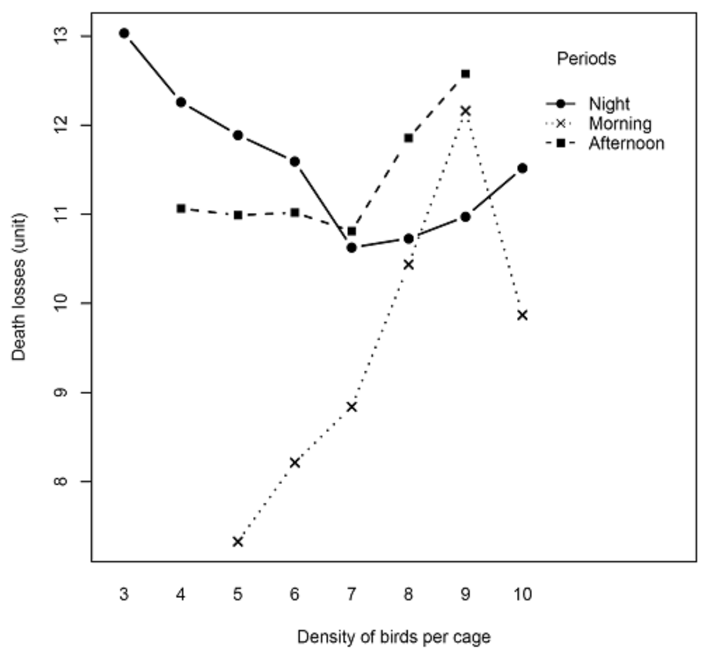

Figure 3. Interaction between density of birds per cage and the different daily periods, in relation to the number of dead broilers.

Reduction in the birds per cage was related to increase in mortality. This find is supported by several factors studied in this research. During 2006, lower temperatures and higher ambient relative humidity were registered during the night, added the low density of birds per cage. In this situation the bird already presents an exchange of thermal energy through sensitive heat (conduction, convection and radiation) to the environment, according Furlan and Macari (2002) and the animal tries to compensate her losses through thermogenesis mechanisms, to reduce the heat transferring to the environment.

With added ventilation, the animal's body cannot reverse the stress of cold in trying to achieve homeostasis and quickly arrives to death. In moderate cases, birds can still survive, but types of productive losses result. These results were consistent with several previous results (Hunter et al., 2001; Furlan & Macari, 2002; Nijdam et al., 2004; Delezie et al., 2007).

The high density per cage certainly reduces the cost of transport, but this excess can lead to heat stress, reducing their ability to exchange heat with the environment, as reported by Delezie et al. (2007), and an increased rate of mortality. Ventilation also cause stress for heat, due to heterogeneity in the microenvironment of the thermal load, as described by Hunter et al. (2001). So, in high densities (7 to 10 birds per cage), even the environmental temperature is low or comfort, this situation can lead the microenvironment to increase in temperature, reducing the ability to exchange sensible heat and facilitates the exchanges of latent heat (respiratory evaporative cooling). However, Nijdam et al. (2004) related that the increased density leads to increased relative humidity inside the load through the respiratory tract (panting), making it more difficult the exchange latent heat in a situation of heat stress. This situation is more characteristic in the morning and afternoon, as discussed below.

The result found for the afternoon (Figure 3) showed a gradual elevation in the mortality with the increasing of the density per cage. In the range between 4 to 6 birds per cage, the mortality rate has remained constant, until the density of 7 birds, from which it is observed a sharp increase in mortality. These results are similar to what happened in the part of the night.

In the afternoon, the basic bioclimatic characteristics are higher temperatures and lower relative humidity. This condition leads the birds to make physiological and behavioral adjustments to maintain thermal balance. Analyzing the model of interaction between daily periods with a change in temperature (Figure 4), with the increase of temperature there was a rise in mortality. This observation was evidenced for the part of the afternoon, where the sudden increases in mortality occurred in the ranges above 22 ºC, considered the warning, which is accentuated with increasing density. Thus, there is a direct relationship between the number of birds per cage, temperature and mortality. This corroborates with Nicol and Scott (1990), which reported that the form of sensible thermal exchange to the environment is reduced due to the high density of birds per cage in the truck, in general, twice as that adopted on farm. This information was supplemented by Yahav et al. (2005), which reported that the strength guideline of the sensible heat loss is the difference in temperature between the animal surface and the environmental temperature. Once the birds have considerable feather coverage, the body's temperature remains close to the environment, making it less effective to lose heat by radiation or convection. Thus, the birds use more intensively respiratory evaporation as a way to remove the excess body heat, but increasing ventilation of the load can lead the bird to dehydration and consequently a further increase in the core body temperature, resulting in an increase in mortality rate. Otherwise, the respiratory evaporative cooling is around 40% in the removal of metabolic heat of the birds, consisting of an efficient way to exchange heat with the environment (Silva, 2000).

Increase of ambient temperature, whilst the ventilation rate is low on the load, can rise the respiratory rate of birds and also increasing the amount of moisture in the microenvironment, which generates a vicious circle resulting in increase in heat stress to the birds (Mitchell and Kettlewell, 1998). Moreover, Furlan and Macari (2002) reported that the increase in respiratory rate can cause metabolic disturbances on the acid-base imbalance of the chickens, developing a framework of respiratory alkalosis. Thus, with the extension of the preslaughter operations, the birds come to death.

Already in the morning, from 5 birds per cage there is an increase in mortality, with further stressing from 7 birds per cage. This reduction is similar to the afternoon. Due to the fact the morning is a transition period between the night and part of the afternoon, variation of increasing mortality in relation to the density of birds per cage was expected, following the increase of temperature (Figure 4), whilst the relative humidity remains high in the morning hours, dropping with time. Overall, in the morning, it was observed that the increase of the density per cage, at higher temperatures, can affect the bird's heat loss to the environment, or the discomfort of the birds can reach the critical levels, as evidenced in these results of this work. Based on similar results, Nijdam et al. (2004) analyzed the different daily periods and found mortalities expressive periods in the morning and afternoon, explaining that during the day, the degree of activity of the animals increased considerably, generating from injury in the carcasses to the mortality. Considering the transition of moisture seen in this part, Yahav et al (1995) observed that when the water balance of the bird is limited, as occurs in conditions of low relative humidity, disturbances in thermoregulation can be expected. Thus, the interference with the bird's welfare is due to hyperthermia, reducing productive performance. At this point, Bayliss and Hinton (1990) reported that during the morning, with the temperature increase over the hours, the mortality accompanies the increase of heat until the temperature reaches a plateau and mortality will increase. The data of this study showed an increase more pronounced than in the research conducted by the same author in 1985. However, the data was in agreement with the reporting about the mortality rate, although rising, is still low in relation to the turn of the afternoon, considered the period of increased mortality of the day.

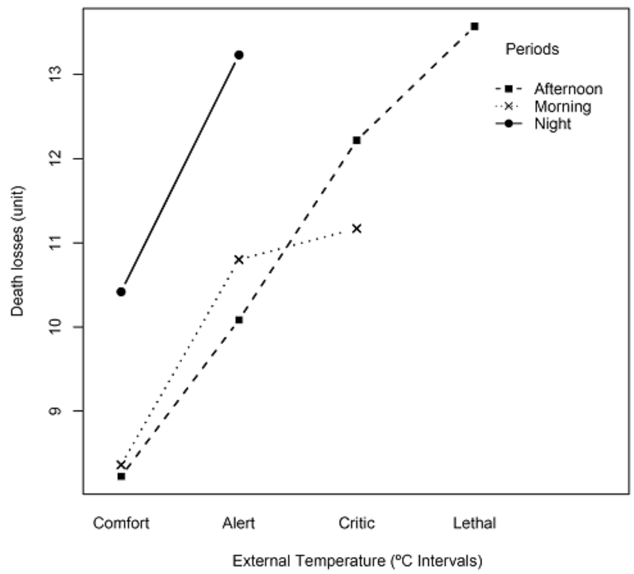

Figure 4. Interaction between the daily periods and external temperature. Temperature range: Comfort: lower than 21 ºC; Alert: 22 – 24 ºC; Critic: 25 – 28 ºC; Lethal: above 28 ºC.

Thus, according to the results presented above, it can be concluded that in relation to high densities (above 7 birds per cage), there was an increase in mortality at the afternoon, followed by part of the morning and evening, due to the temperature high in the first two periods, combined with the effect of moisture on these periods. In lower densities (under 7 birds per cage), the mortality rate was high in the round of the night, followed by afternoon and the morning due to the effect of the loss of sensitive heat and the number of dead birds was lower due to the greater space for heat exchange within the cages.

As for the best daily periods to carry out the pre-slaughter operations, Nijdam et al. (2004) found higher rates of mortality in the morning and afternoon and the smaller losses during the night, recommending the pre-slaughter management in the range between 0 and 5 hours. As to the density of birds per cage, Delezie et al. (2007), recommended an area of approximately 5.76 cm^2, which found in the measures adopted at the slaughterhouse cages (70 x 60 cm), equivalent to the density range between 7 and 8 birds per cage. However, it should be considered such recommendations in each period in which the transportation was carried out.

Therefore, in accordance with the results analyzed in this study, it can be recommended that the best densities of birds per cage related to the lower losses were 5 birds per cage at the morning and 7 birds per cage during the afternoon and night (Table 3).

Table 3. Recommended values for density per cage transported in different daily periods and their expected mortality rates.

Periods	No. of birds per cage	% of expected mortality
Morning	5	0.30*
Afternoon	7	0.32*
Night	7	0.31*

* Significant difference (P<0.005), derived by Wald Test.

Conclusion

For different densities of birds in cages to be adopted within different periods, the best density adopted was 5 birds per cage in the morning and 7 birds per cage periods in the afternoon and evening. However, the observation of thermal conditions of the external environment must be considered in the adoption of rational pre-slaughter management, aiming the bird's welfare and the reduction of mortality.

Acknowledgements. The first author is supported through a scholarship by FAPESP – Fundação de Amparo à Pesquisa do Estado de São Paulo.

References

Adams, R. L. and J. C. Rogler. 1968. The effects of dietary aspirin and humidity on the performance of light and heavy breed chicks. *Poul. Sci.* 44: 1344-1349.

Barbosa Filho, J.A.D. 2005. Welfare evaluation by image analysis of laying hens in different housing systems and environment conditions. Piracicaba, São Paulo. 123 p. *Thesis* (MSc in Phisics of Agricultural Environment) - Superior School of Agriculture Luiz de Queiroz, University of São Paulo.

Barbosa Filho, J.A.D.; Vieira, F.M.C.; Garcia, D.B.; Silva, M.A.N.; Silva, I.J.O. *Alteration and the using of Enthalpy Tables*. Piracicaba, 2007. Available at: www.nupea.esalq.usp.br. Accessed 15 August 2007.

Bayliss, P.A.; Hinton, M.H. 1990. Transportation of Broilers with Special Reference to Mortality Rates. *Applied Animal Behaviour Science*. 28: 93-118.

Curtis, S.E. 1983. *Environmental management in animal agriculture*. Ames: The Iowa State University Press. 400 p.

Delezie, E. et al. 2007. The Effect of Feed Withdrawal and Crating Density in Transit on Metabolism and Meat Quality of Broilers at Slaughter Weight. *Poultry Science*.86: 1414-1423.

Furlan, R.L.; Macari, M. 2002. Thermorregulation. In: Macari, M.; Furlan, R. L.; Gonzales, E. (Ed.). *Avian physiology applied to broiler chickens*. Jaboticabal: FUNEP/UNESP. 17: 209 - 230.

Hunter, R.R.; M.A. Mitchell, C. 2001. Matheu. Mortality of Broiler Chickens in Transit – Correlation with the Thermal Micro-Environment. In: International Symposium, 6., *Proceedings…*21-23 May 2001, Louisville, Kentucky, USA. p. 542-549.

Macari, M. and R.L. Furlan. 2001. Environment science on poultry production under tropical climate. In: Silva, I.J.O. (Ed.). *Environmental Science on Poultry Production under Tropical Climate.* Piracicaba: FUNEP. 1: 146-164.

Milligan, J.L. and P.N. Winn. 1963. The influence of temperature and humidity on broiler performance in environmental chambers. *Poul. Sci.* 33: .817-824.

Mitchell, M. A.; Kettlewell, P. J. 1998. Physiological Stress and Welfare of Broiler Chickens in Transit: Solutions Not Problems! *Poultry Science.* 77: 1803-1814.

Nicol, C.J.; Scott, G.B. 1990. Pre-slaughter handling and transport of broiler chickens. *Applied Animal Behaviour Science*. 28: 57-73.

Nijdam, E. et al. 2004. Factors Influencing Bruises and Mortality of Broilers During Catching, Transport, and Lairage. *Poultry Science*. 83: 1610-1615.

Petracci, M. et al. 2006. Preslaughter Mortality in Broiler Chickens, Turkeys and Spent Hens Under Commercial Slaughtering. *Poultry Science*. 85: 1660-1664.

R Development Core Team. 2006. R*: A Language and Environment for Statistical computing.* Vienna: R Foundation for Statistical Computing. Available at www.R-project.org. Accessed 05 May 2007.

Silva, R.G. 2000. *Introduction to Animal Bioclimatology***.** Sao Paulo: Nobel. 286 p.

Smyth, G. K. and A.P. Verbyla. 1999. Adjusted likelihood methods for modeling dispersion in generalized linear models. *Environmetrics*. 10: 695-709.

Vecerek, V. et al. 2006. Effects of travel distance and the season of the year on death rates of broilers transported to poultry processing plants. *Poul. Sci.* 85: 1881-1884.

Yahav, S. et al. 1995. Physiological responses of chickens and turkeys to relative humidity during exposure to high ambient temperature. *Journal of Thermal Biology.* 20(3): 245-253.

Yahav, S.; Shinder, D.; Tanny, J.; Cohen, S. 2005. Sensible heat loss: the broiler's paradox. *World's Poultry Science Journal*. 61(3): 419-434.