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PREDICTION OF MEAN SURFACE TEMPERATURE OF BROILER CHICKS AND LOAD MICROCLIMATE DURING TRANSPORT

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ABSTRACT: This study aimed to determine a model to predict mean surface temperature of broiler chicks and live load microclimate conditions during transport by using neural networks. The research was conducted in the state of São Paulo, Brazil, by monitoring nine shipments with different density of boxes using an air-conditioned truck with an average capacity of 380 boxes. Fourteen chick boxes were chosen on each shipment, assessing five chicks per box. The mean surface temperature of chicks (MST) was measured with an infrared thermometer in both loading and unloading. By assessing the container microclimate (center and inside boxes), air temperature (T), relative humidity (RH) and specific enthalpy (h) were recorded; thereby, seventeen data loggers were placed, one per box (14), and three along the container. MST and truck microclimate were analyzed using artificial neural networks with a single layer and seven neurons, which were trained with the least mean square (LMS) algorithm. MST in the unloading showed a better prediction of MST during transport. The best prediction of microclimatic conditions was obtained inside the boxes during the shipment.

KEY WORDS: poultry, ambience, neural networks, air-conditioned truck.

INTRODUCTION

Transport of day-old chicks increases stress and compromises animal welfare, in addition to interfere with the production performance (VALROS et al., 2008; BERGOUG et al., 2013). Some of the biggest issues of shipping alive chicks in air-conditioned trucks are related to thermal heterogeneity inside containers and inadequate air circulation (QUINN & BAKER, 1997; NAZARENO et al., 2015a, 2015b), resulting in possible economic losses.

The ideal microclimate for day-old chick transport varies because inside the transport container there are two different environments (container environment and inside chick boxes). Both of them have certain peculiarities related to air temperature and relative humidity. In this sense, MARQUES (1994) recommended container temperatures between 22 and 31 °C and relative humidity of 50%. However, NAZARENO et al. (2015a, 2015b) suggested an air temperature range and relative humidity inside chick boxes of 32–35 °C and 50–60%, respectively.

Currently, a thermal gradient between the two environments of chick loads is still unknown and hence its possible effects on animal physiological responses such as average surface temperature. Maintenance of body temperature in birds is highly affected by microclimate conditions (YAHAV et al., 2009; NASCIMENTO et al., 2014). For day-old chicks, the ideal average surface temperature ranges from 31.6 to 36.9 °C (MARCHINI et al., 2007; ABREU et al., 2012; NASCIMENTO et al., 2013). According to LIN et al. (2005) and NÄÄS et al. (2014), chick surface temperature is similar to the environment one, which explains its reduced ability to lose thermal energy in sensible form under high temperatures. In this context, artificial neural networks (ANN) can be a tool to assist in a microclimatic assessment of day-old chicks load and its effect on animal mean surface temperature.

Several studies have used ANN to predict the production performance in inspecting broiler chicken carcasses through images, separating the healthy from the sick (PARK et al., 1998; CHAO et al., 2002; SALLE et al., 2003). XIONG et al. (2015) used an ANN tool to match spectral imaging data spectra and texture, and could differentiate broiler chicken meat reared in the outdoors and

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under conventional system. VIEIRA et al. (2011) also applied ANN in the pre-slaughter mortality simulation of broiler chickens.

In order to contribute positively in dimensioning acclimatization systems of container truck for chick shipping, this study aimed to determine a model to predict mean surface temperature of broiler chicks and live load microclimate during transport by means of neural networks.

MATERIAL AND METHODS

The research was conducted in a broiler hatchery of an integrated company located in São Paulo State, Brazil. The area lies at a latitude of 22º 25’ 55” S and 46º 57’ 28” W longitude, with an altitude of 632 m and atmospheric pressure of 761.98 mmHg. The experimental period was of three months, with monitoring of nine shipments of day-old chicks, during the spring and summer seasons.

The same container truck was used in all shipments, consisting of a Volkswagen Constellation 26–370, 6 x 4 tractor, 8 m long, 2.5 m wide and 2.5 m high, with two axes (Figure 1). The truck body was coated internally and externally with aluminum, with thermal insulation of expanded polyurethane. The doors were made of three layers of stainless steel, fully sealed. Inside, there were three rows (center, left and right side) with spacing of 0.7 m. The sides were longitudinally divided into 2 shelves, with approximate vertical spacing of 0.81 m.

FIGURE 1. Container truck and view of a day-old chick box.

Sensors controlled the truck internal temperature, ventilation, and humidity; load environmental moistening was carried out by a centrifugal humidifier or pressurized air nozzles digitally controlled by an electronic system in the truck cabin. Thermal control was set to a temperature range between 23 and 25 °C and relative humidity between 60 and 70%. The truck’s air-conditioning system was located in front of its body shell, with part of the air circulation distributed through floor vents and air vents located in the openings of the body shell roof (truck ridge vent). It is noteworthy that the acclimatizing system was only activated when the truck was moving.

The boxes used for the transport of chicks had 42 cm wide, 57 cm long, 15 cm high and thickness of 2.5 mm. These crates were provided with 26 ventilators of 1 cm wide and 6.5 cm high around. Under normal conditions, these boxes were stacked considering animal density and the company’s delivery logistics; the last one received a perforated lid to enable minimal air movement throughout the animals during transport.

The truck carrying capacity was approximately 380 boxes with 100 chicks each distributed among rows in the container. However, each shipment showed different densities of chick boxes (1 = 450, 2 = 470, 3 = 450, 4 = 420, 5 = 420, 6 = 360, 7 = 240, 8 = 308, 9 = 300) since the company had a delivery schedule to follow and it could not be changed.

On each shipment, 14 chick boxes with Cobb Fast strain were selected and five birds were collected randomly from each of them during loading and unloading to take body surface temperatures (head, back, wing and paw). For that, a Fluke infrared thermometer was used to measure the mean surface temperature (MST) for the first week rearing, according to [eq. (1)] proposed by NASCIMENTO et al. (2013):

$$MST = 0.10 * th + 0.56 * td + 0.11 * tw + 0.15 * tp + 3.7 \quad (1)$$

where,

th is the head surface temperature (°C);

tb is the back surface temperature (°C);

tw is the wing surface temperature (°C), and

tp is the paw surface temperature (°C).

To characterize the thermal environment, air temperature (T, °C) and relative humidity (RH, %) were recorded by using 17 data loggers Onset, model Hobo®. It was added a data logger inside each of the 14 chick boxes selected on each shipment, which were randomly distributed throughout the container. Furthermore, three data loggers were positioned at the center of the container (central measurements). The equipment was programmed for recording data at 10-minute intervals.

To evaluate the predictions of mean surface temperature of broiler chicks and load microclimate during transport, it was conducted a machine learning (MA) study using artificial neural networks (ANN) with a single layer and seven neurons trained with the least mean square (LMS) algorithm. The seven neurons were air temperature in the container (T_{cont}) and inside the chick boxes (T_{box}), relative humidity in the container (RH_{cont}) and inside the chick boxes (UR_{box}), and mean surface temperature of chicks during the shipment ($MST_{shipment}$), loading (MST_{load}) and unloading (MST_{unload}), interspersed as input and output variables. In addition, a linear regression function was used from the implementation of the LMS algorithm in order to choose the best set of observations adjusted, minimizing the squared residuals.

The results were obtained using the 10-fold cross validation, according to the methodology used by MITCHELL (1997), SILVA et al. (2008a, 2008b), ATA (2015) and SEVEGNANI et al. (2016). The sampling method 10-fold cross validation partitions the total data set into 10 equal parts, using nine parts to train and one to test. Thus, it was performed 10 different training and 10 different tests.

Sampling techniques for handling the training and test sets were used to obtain an unbiased estimate of classifier error (SILVA, 2008a, 2008b). For this purpose, it was used the r-fold cross-validation method, which splits the total data set of n size in r parts mutually exclusive (folds) with sizes equal to n/r samples. The samples in the (r −1) folds are used for training and the induced hypothesis is tested in the remaining fold. This process is repeated r times, each time considering a different fold for testing. The error in the cross-validation is the average of errors calculated in each of the r folds test (EFRON & GONG, 1983; EFRON & TIBSHIRANI, 1993; BARANAUSKAS, 2000).

In these analyses, it was first verified the degree of correlation between the defined model and the different variables or sets of variables, using the software WEKA 3-7-13. Subsequently, the best correlations (Pearson) were subjected to linear regression analysis by using the LMS algorithm.

For the ANN analyses, it was used the computational tool in the public domain WEKA 7-3-13 (THE UNIVERSITY OF WAIKATO, 2013).

The selection of these variables (T_{cont}, T_{box}, RH_{cont}, RH_{box}, $MST_{shipment}$, MST_{load} and MST_{unload}) was based on microclimate and mean surface temperature estimations required during shipping to monitor thermal stress from hatchery to poultry farm, since there is a lack of information on this pre-farm gate stage (transport of day-old chicks).

Descriptive analysis such as standard deviation and variation coefficient were performed using the statistical software SAS (SAS, 2010). The other descriptive variables (average, minimum, maximum and standard deviation) were performed using WEKA.

RESULTS AND DISCUSSION

In the descriptive analysis of the average surface temperature of the way of the day-old chicks from the hatchery to the poultry farm, $MST_{shipment}$, MST_{load} and MST_{unload} presented arithmetic averages respectively of 36.1, 35.2 and 37.1 °C, with maximum values of 38.2, 37.2 and 40.0 °C and minimum of 32.7, 31.8 and 30.9 °C (Table 1).

TABLE 1. Descriptive analysis of the variables mean surface temperature of chicks (MST) during the shipment, loading and unloading, air temperature (T) and relative humidity (RH) in the container of chick boxes during transport.

Variable	Average	Minimum	Maximum	Standard deviation	Standard error	CV (%)
$MST_{shipment}$ (°C)	36.1	32.7	38.2	1.090	0.043	3.020
MST_{load} (°C)	35.2	31.8	37.2	0.996	0.040	2.882
MST_{unload} (°C)	37.1	30.9	40.0	1.942	0.077	5.233
T_{cont} (°C)	28.5	23.3	32.18	2.882	0.115	10.10
RH_{cont} (%)	40.5	31.4	54.1	8.605	0.344	21.20
T_{box} (°C)	32.4	29.2	35.9	1.993	0.079	6.558
RH_{box} (%)	47.8	38.1	57.6	5.722	0.288	11.967

CV = coefficient of variation; $MST_{shipment}$ = mean surface temperature of chicks during the shipment; MST_{load} = mean surface temperature of chicks in the loading; MST_{unload} = mean surface temperature of chicks in the unloading; T_{cont} = air temperature in the truck container; T_{box} = air temperature inside the boxes; RH_{cont} = relative humidity in the truck container; and RH_{box} = relative humidity inside the boxes.

According to MARCHINI et al. (2007), ABREU et al. (2012) and NASCIMENTO et al. (2013), $MST_{shipment}$ was within the recommended levels, which range from 31.6 to 36.9 °C. For MST_{load}, only the maximum value was out of the optimum range of the average surface temperature. It was also noted that for MST_{unload} all values were out of the optimum range, thus demonstrating that the unloading caused thermal stress in the chicks due to their greater permanence under adverse microclimatic conditions during the transport. Several reports in literature state that charging (loading and unloading) in live load transport is considered one of the most stressful components, which is due to microclimatic variations, airflow, animal management, etc. These alterations may affect animal physiology, increasing rectal and surface temperatures, cortisol levels, as well as heart and respiratory rates (ONMAZ et al., 2011; TATEO, et al., 2012).

Surface temperature standard deviation showed low dispersion between the data and a homogeneous distribution, as in SINGH & MATHUR (2005) and LÓPEZ-FIDALGO & RIVAS-LOPEZ (2007), with values of 1.090, 0.996 and 1.942 respectively for $MST_{shipment}$, MST_{load} and MST_{unload}.

The standard error provides an indication of the probable accuracy of the sample average as an average estimation of population. Therefore, the lower the standard deviation is, the lower the dispersion (SAMPAIO, 2007; LIUA et al., 2016). Given the above, the standard error values of the variables $MST_{shipment}$, MST_{load} and MST_{unload} showed a low dispersion between the data and a homogeneous distribution. Furthermore, the standard errors were lower (0.043, 0.040 and 0.077, respectively) than the standard deviations; therefore, a low standard deviation results in a low mean standard error and more accurate data estimation. The variables $MST_{shipment}$, MST_{load} and MST_{unload} evidenced low coefficients of variation (3.020, 2.882 and 5.233%, respectively), demonstrating homogeneity and low dispersion ($CV \leq 15\%$) of the data (SAMPAIO, 2007).

Studies on chick surface temperature are extremely important due to their similarity to ambient temperature, which explains the reduced ability of birds to lose thermal energy in sensible form at elevated temperatures (LIN et al., 2005; NÄÄS et al., 2014). However, it is known that the existing thermal gradient between the body surface temperature and the air temperature in cold conditions expands significantly due to the lower thermoregulatory capacity of the day-old chicks and their ease in losing thermal energy to a cooler environment (GUSTIN, 2003).

For the variables air temperature (T_{cont}) and relative humidity (RH_{cont}) in the container, it was found that the average values were, respectively, 28.5 °C and 40.5%, with a maximum of 32.2 °C and 54.1% and a minimum of 23.3 °C and 31.4%. These results showed that only the maximum value of air temperature in the container was out of the ideal range (22–31 °C). Furthermore, container average, maximum and minimum relative humidity were out of the recommend (50%) for ideal microclimate conditions of chick transport trucks, as in MARQUES (1994).

The standard deviations of T_{cont} (2.882) and RH_{cont} (8.605) were low, in addition to present a low dispersion between the data. The same was observed for the standard error, which presented a low dispersion between the data and a homogeneous distribution for these variables (SAMPAIO, 2007; LIUA et al., 2016). Because the standard errors were lower than the standard deviations, with values of 0.115 (T_{cont}) and 0.344 (RH_{cont}), it can be inferred that there was an accurate estimate of the data. The coefficient of variation of T_{cont} was low (10.10%), demonstrating the homogeneity and low dispersion ($CV \leq 15\%$) of the data. In its turn, RH_{cont} presented a medium coefficient of variation (21.20%) ($15\% < CV < 30\%$) and medium data dispersion (SAMPAIO, 2007).

Based on the air temperature and relative humidity inside the chick boxes (T_{box} and RH_{box}), it was possible to analyze the average, maximum and minimum values (32.4, 35.9 and 29.2 °C, and 47.8, 57.6 and 38.1%, respectively). Thus, it was observed that only the average temperature and the maximum relative humidity values were within the recommended range of 32–35 °C and 50–60%, respectively (NAZARENO et al., 2015a; 2015b). In addition to that, these variables had low standard deviations (1.993 and 5.722, respectively), demonstrating a homogeneous data distribution, as in SINGH & MATHUR (2005) and LÓPEZ-FIDALGO & RIVAS-LOPEZ (2007).

The T_{box} and RH_{box} standard errors showed low dispersion between the data and a homogeneous distribution (SAMPAIO, 2007; LIUA et al., 2016). Thus, the standard errors were lower (0.079 and 0.288, respectively) than the standard deviations; a low standard deviation results in a low mean standard error and in a more accurate estimate of the data. Moreover, the coefficient of variation of T_{box} (6.556%) and RH_{box} (11.967%) were low, demonstrating the homogeneity and low dispersion ($CV \leq 15\%$) of the data (SAMPAIO, 2007).

The microclimate variables are extremely important in the broiler chick physiology, mainly for body temperature maintenance (YAHAV et al., 2009; NASCIMENTO et al., 2014). Therefore, when these variables are not respected during transport, it may affect the animal performance and its welfare (VALROS et al., 2008; BERGOUG et al., 2013).

The temperature above the recommended could induce the chicks to hyperthermia with dehydration, leading to a reduction in feed intake and growth retardation. However, temperatures below the ideal range may trigger hypothermia and induce pulmonary hypertension syndrome in broilers (MICKELBERRY et al., 1966; CASSUCE et al., 2013). The latent heat loss is influenced by the relative humidity, as it increases with the air temperature and reduces with the increase in relative humidity (LIN et al., 2005; SCHMIDT et al., 2009). Therefore, when the relative humidity is below the range of 50%, the heat exchange between the animal and the environment by latent pathway are high, which may cause ascites syndrome, whose consequence is the mucous membrane dehydration of chicks in the first weeks of life (MUJAHID & FURUSE, 2009).

Through the data of the variables used as input and output were developed the following regression models: prediction of the internal microclimate of chick boxes (T_{box}) and prediction of the mean surface temperature of chicks during transport (MST_{unload}) (Table 2).

TABLE 2. Regression model estimated as a function of the mean surface temperature (MST_{unload}) and air temperature (T_{cont} and T_{box}) during transport of day-old chicks.

Equation	Regression equation	Correlation coefficient (r)	R^2
1	$T_{box} = 0.5685\ T_{cont} + 16.0909$	+0.954	0.910
2	$MST_{unload} = 0.3734\ T_{box} + 25.5358$	+0.784	0.614

MST_{unload} = mean surface temperature of chicks in the unloading; T_{cont} = air temperature in the truck container; T_{box} = air temperature inside the boxes.

The selection of these equations was based on the highest values of the correlation coefficient and R^2, as MITCHELL (1997), SILVA et al. (2008a, 2008b), ATA (2015) and SEVEGNANI et al. (2016). These models showed a positive correlation coefficient, which according to AYDIN et al. (2015) it means that the studied variables are mutually dependents to each other and tend to increase or decrease simultaneously.

Equation 1 (T_{box}) presented a very strong ($P \geq 0.70$) and positive (+0.954) correlation coefficient, according to SAMPAIO (2007). For this reason, the container temperature was the variable that presented the greatest influence on the temperature inside the chick boxes. Thus, it can be said that through the container temperature is possible to predict the air temperature inside the chick boxes using this model.

The air temperature inside the chick boxes (T_{box}) expresses the microclimate closest the chicks due to the close proximity of broiler chicks inside the boxes (density of 100 chicks per box), thus generating a larger energy supply (heat release to microenvironment), which consequently increases T_{box}. According to HELLICKSON & WALKER (1983), a 2.1-kg broiler chicken emits 20 W of energy in a density 12 chicks m^{-2}. In the container macro-environment (T_{cont}), this energy is dissipated in a larger space compared to the internal environment of boxes; for this reason, the container temperature tends to be lower. According to ÇENGEL & BOLES (2001), the temperature goes out of a warmer environment (T_{box}) to a cooler (T_{cont}) and tend to match up with air temperatures.

By examining the two transport environments, it is inferred that the acclimatization system efficiency of the trucks used for chick transport can be improved. Furthermore, the non-standardization of load densities in the chick transport is another factor that complicates the acclimatization system efficiency of trucks due to higher and/or lower supply of energy generated by the chicks during their transport (QUINN et al., 1997; NAZARENO et al., 2015a, 2015b).

Equation 2 (MST_{unload}) was the model that best adjusted to the mean surface temperature prediction, since it got a strong ($P \geq 0.70$) and positive (+0.784) correlation coefficient. According to SAMPAIO (2007), this model demonstrated a strong influence of the air temperature inside the chick boxes on the AST during unloading, depending on the increase/decrease of this microclimate variable.

Through these results, it can be inferred that the equation 2 obtained a better performance to predict the mean surface temperature of day-old chicks during transport, making it a great alternative to predict their thermal stress on the poultry farm arrival. Additionally, the air temperature inside chick boxes has most influence on this formula since such environment surrounds closely the chicks, biasing bird surface temperature. For LIN et al. (2005) and NÄÄS et al. (2014), such fact is related to the reduced ability of chicks in losing thermal energy appreciably under high temperatures.

GILOH et al. (2012) observed a high correlation coefficient between chick surface temperatures and environmental variables, confirming that air temperature, relative humidity and air circulation are major factors affecting poultry performance. The variations on body surface temperature are directly related to peripheral blood flow, indicating bird attempt to keep a constant corporeal temperature.

This research aimed at improving the acclimatization system design of container trucks used for broiler chick shipping, proposing reductions in inner thermal pockets and minimizing transport losses (culling, body mass loss within the first three weeks and mortality) assigned to the container microclimates, in addition to improve thermal comfort on the way from hatchery to poultry farms.

CONCLUSIONS

According to the results obtained in this research, the mean surface temperature of birds in unloading (MST_{unload}) presented a better prediction for day-old chicks during transport, in which the air temperature inside chick boxes had most influence on construction of the formula.

Regarding the load microclimate, it was found that the air temperature inside chick boxes (T_{box}) showed a better prediction since this environment is closer to the birds.

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