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CLOACAL AND SURFACE TEMPERATURES OF BROILERS SUBJECT TO THERMAL STRESS

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ABSTRACT: The cloacal and surface temperatures are important physiological parameters to quantify the thermal comfort of animals, its variations may occur as a function of thermal variables. In this context, the goal of the present study was to evaluate the cloacal (t_{clo}) and surface (t_{sur}) temperatures of *Cobb* 500® broilers, in the second week of life, subjected to different air dry-bulb temperature (24, 27, 30 and 33 °C) and stress durations (1, 2, 3 and 4 days). The experiment was carried out in four climate-controlled wind tunnels. Air relative humidity and air velocity were set at 60% and 0.2 m s^{-1}, respectively. The t_{clo} and t_{sur} were measured daily through digital thermometer and thermographic camera, respectively. Analysis of variance and Scott Knott mean test at 5% probability were applied to the data. The results indicate that the stress by low air temperature (24 and 27 °C) resulted decreased of t_{clo} and t_{sur} ($p<0.05$, Scott-Knott test). When subjected to high air temperature stress (33 °C), there was no significant difference ($p>0.05$, Scott-Knott test) compared to the control treatment (30 °C). Acclimation of broilers to thermal stress occurred from the second day of stress.

KEYWORDS: animal environment, aviculture, thermal comfort, thermographic image, physiologic parameters.

INTRODUCTION

Brazil, a country with a large territorial extension presents great climatic diversity with temperature amplitudes during the year, in which promotes complications in the broilers breeding due to the variations that occur in the environment production (Nääs et al., 2010).

Thus, in the current scenario of Brazilian poultry development it is necessary that the poultry be raised in appropriate environments so they can achieve high performance maximizing their genetic potential. Under these conditions, characterized as thermal comfort, obtain low energy expenditure to control the homoeothermic thus increasing the performance (Nascimento et al., 2014).

The cloacal (t_{clo}) and surface (t_{sur}) temperature are among the main physiological indicators for thermal comfort on broilers, as they change with the variation of air dry bulb temperature (t_{db}), relative humidity (RH) and luminosity (Costa et al., 2012; Ferreira et al., 2012). When t_{sur} and t_{clo} variation occur, the broilers dissipate or retain heat, and part of the energy that should use to gain weight will be applied in the thermoregulatory process reducing productive responses.

Any variation in body temperature of broiler indicates that the performed changes on their surface were not enough to maintain the thermal equilibrium (Nascimento et al., 2013) indicating physiological changes.

The increase of t_{clo} is proportional to the age (Marchini et al., 2007), and the stress caused by high t_{clo} results in decrease in weight gain (Costa et al., 2012). According to Oliveira et al. (2006) the body core temperature for the second week of life varies between 41 to 42 °C consistent with the values found by Bueno et al. (2014).

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According to Nääs et al. (2014), through skin analysis temperature it is possible to determine the physical healthy state of the animal. One way to evaluate the t_{sur} on broilers is through infrared thermography which is a procedure that does not cause interference in the ecological niche of the evaluated animal (Nascimento et al., 2011a).

Although feathers obstruct the infrared emission of the skin, the thermography allows the thermal mapping of the body (Castilho et al., 2015; Souza Junior et al., 2013) and is used in several studies to obtain the thermal responses (Barnabé et al., 2015; Mayes et al., 2014; Roberto & Souza, 2014), since the variation of the t_{sur} is instantaneously modified when thermal changes occur in the thermal environment of the breeding.

The aim of this study was to evaluate the average surface and cloacal temperature on broilers in the second week of life submitted to different intensities and duration of thermal stress, adjusting correlation equations between these variables.

MATERIAL AND METHODS

This research was carried out in an animal environment laboratory equipped with two air conditioning systems 18,000 BTUs each used to control and maintain room air temperature. It also contains four climate-controlled wind tunnels. Inside each wind tunnels there was a cage with dimensions of 0.40 x 0.60 m divided into three sub-distributions equal to 0.08 m² each, equipped with feeders and water fountains.

Two hundred and forty males and females broilers *Cobb* 500® lineage were used from same commercial hatchery, of one day of life. For each stage were used sixty broilers with distribution of five broilers per division during the first seven days of life, that is, fifteen broilers per tunnel. Subsequently, in the second week of life, only four chicks were kept in each replicate maintaining the breeding density recommended by the manual (Cobb, 2012).

During the experimental period the broilers were fed with a balanced diet based on corn and soybean, following the nutritional recommendations by Rostagno et al. (2011). Feed and water were available *ad libitum*. The hygienization of the wind tunnels and cages was carried out every day to avoid formation of gases, providing an adequate environment for broilers performance. The t_{clo} and t_{sur} of the poultries were also daily evaluated.

The experiment was carried out in different stages varying the intensity of t_{db} applied on broilers on second week of life. In the first seven days, the birds were kept in thermal comfort at 33 °C (Cony & Zocche, 2004). From the eighth day, the t_{db} levels at each stage were 24, 27 and 33 °C, in order to provide thermal stress at both low and high air temperatures (Cony & Zocche, 2004; Curtis, 1983).

The thermal stress was applied in four levels of duration and performed on days 8, 9, 10 and 11 of the experimental period of each stage. During the second week, the air temperatures returned to thermo neutrality zone. Table 1 shows how the treatments were divided.

For the experiment, the air relative humidity was maintained at 60 ± 1% and air velocity at 0.2 ± 0.1 m s^{-1}, characterized as comfort for broilers (Medeiros et al., 2005). The illuminance was adjusted by means of a luxmeter (LDR-380, accuracy of ± 3%), with intensities of 25 and 10 lux for the first and second week of life, respectively (Cobb, 2012).

TABLE 1. The air dry-bulb temperature and days of maintenance of heat stress condition (in bold), applied to broilers from 1 to 21 days of age kept in climate-controlled wind tunnels.

Stage	**Tunnel**	**Air dry-bulb temperature (°C)**							
		Days of Life							
		1 to 7	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	A	33	**33**	30	30	30	30	30	30
	B		**33**	**33**	30	30	30	30	30
	C		**33**	**33**	**33**	30	30	30	30
	D		**33**	**33**	**33**	**33**	30	30	30
2	A	33	**27**	30	30	30	30	30	30
	B		**27**	**27**	30	30	30	30	30
	C		**27**	**27**	**27**	30	30	30	30
	D		**27**	**27**	**27**	**27**	30	30	30
3	A	33	**24**	30	30	30	30	30	30
	B		**24**	**24**	30	30	30	30	30
	C		**24**	**24**	**24**	30	30	30	30
	D		**24**	**24**	**24**	**24**	30	30	30
4	A, B, C and D	33	30						

Thermographic images were used to obtain surface temperatures. The images were acquired by means of a Fluke thermographic camera (model TI55FT20/54/7.5), positioned 1 meter high from the cage, in order to allow a wide view and comprehensiveness of all the animals.

The thermographic evaluation was elaborated using the Fluke *Smart View* 3.0.126.0 *software*, in which the adopted emissivity was 0.95 (Ferreira et al., 2011; Nääs et al., 2014). For each replicate of the cage a bird was randomly selected (Figure 1) and the average t_{sur} was obtained as a function of the surface areas of three broilers (Case et al., 2012; Nascimento et al., 2011b).

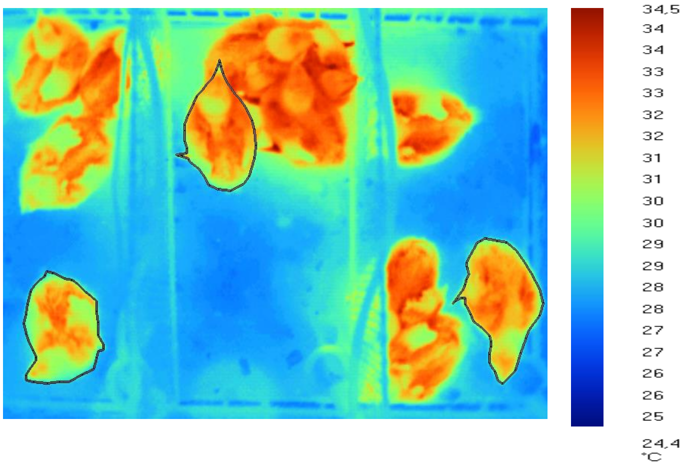

FIGURE 1. Thermographic image of broilers subjected to determined thermal conditions inside the climate-controlled wind tunnels.

With respect to the t_{clo} a broiler from each part of the cage was captured randomly to have its cycle measured, that is, twelve broilers per day totalizing forty-eight verifications per step. The measurement of t_{clo} was performed by digital thermometer (INSTRUTHERM® São Paulo, Brazil, Model THR-080, accuracy ± 0.01 °C), and before each use the sensor was sterilized and introduced into the broilers cloaca, obtaining the value of the t_{clo} until the reading was stabilized (Costa et al., 2012).

For the statistical analysis of the variables was used completely randomized design (C.R.D.) with three replications, assembled according to the 4x4 factorial arrangement, that is, four t_{db} in the second week of broilers life (33, 30, 27 and 24 ˚C) and four stress durations (1, 2, 3 and 4 days), according to equation 1. The variables were treated by the statistical program SISVAR 5.3 (Ferreira, 2010) submitted to variance analysis and comparison means using the Scott Knott test at the 5% probability level. The data were submitted to *clustering* analysis (R Development Core Team, 2012), for the construction of the dendogram of broilers t_{clo} using Ward's method which calculates the smallest sum of squares within the groups (Biagiotti et al., 2015).

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + e_{ijk} \tag{1}$$

In which,

Y_{ijk} is the observation of the repetition k of the *i-th* temperature in the *j-th* duration with *i, j* = 1, 2, 3, 4 and k = 1,2,3;

μ is the constant associated with each observation;

α_i is the effect of the *i-th* temperature;

β_j the effect of the *j-th* duration;

$\alpha\beta_{ij}$ interaction between dry air bulb temperature and duration, and

e_{ijk} error associated with each observation, being $e_{ijk} \sim N(0, \sigma^2)$.

RESULTS AND DISCUSSION

To verify the t_{db} and RH which the broilers were submitted, the thermal environment inside the wind tunnels was monitored during the experimental period. The mean values and standard deviations observed during the second week of life are listed in Table 2.

TABLE 2. Values of air dry-bulb temperature ($t_{db,\ desired}$) and air relative humidity ($RH_{desired}$) desired, means observed ($t_{db,obs}$ and RH_{obs}) and standard deviations (in parentheses) inside the climate-controlled wind tunnels.

Stage	**Thermal variables**	**Stress duration**			
		1 day	**2 dayS**	**3 dayS**	**4 dayS**
1	$t_{db,desired}$ (°C)	24.0			
	$t_{db,obs}$ (°C)	24.3 (0.3)	24.3 (0.3)	24.3 (0.3)	24.3 (0.3)
	RH_{obs} (%)	60.4 (0.7)	60.4 (0.8)	59.9 (1.0)	60.8 (0.6)
2	$t_{db,desired}$ (°C)	27.0			
	$t_{db,obs}$ (°C)	27.2 (0.3)	27.2 (0.2)	27.1 (0.2)	27.2 (0.3)
	RH_{obs} (%)	60.0 (1.6)	60.3 (1.0)	60.0 (0.9)	60.4 (0.9)
3	$t_{db,desired}$ (°C)	33.0			
	$t_{db,obs}$ (°C)	33.0 (0.3)	33.0 (0.3)	33.0 (0.3)	33.0 (0.3)
	RH_{obs} (%)	60.0 (1.7)	60.1 (1.3)	59.9 (1.4)	60.5 (1.3)
4	$t_{db,desired}$ (°C)	30.0			
	$t_{db,obs}$ (°C)	30.2 (0.2)			
	RH_{obs} (%)	60.3 (0.7)			

$t_{db,\ desired}$ = air dry-bulb temperature desired; $t_{db,\ obs}$ = air dry-bulb temperature observed; RH_{obs} = air relative humidity observed.

The observed air dry-bulb temperatures obtained low standard deviations, being close to the desired temperatures (Table 2). The highest standard deviations were 0.3 ° C for t_{db} and 1.7% for RH. These variations indicate the efficiency of climate-controlled wind tunnels in maintaining the desired thermal environment, corroborating with Schiassi et al. (2014).

The interaction between t_{db} and duration of thermal stress for the averages t_{clo} was not significant ($P < 0.05$, test F) however, the different t_{db} and thermal stress durations presented significant difference ($P < 0.01$, Test F), and the means test is listed in Table 3. The lowest t_{clo} (40.5 °C) occurred when the broilers were submitted to the lowest thermal stress of the t_{db} (24 °C) with the t_{clo} observed being below the lower limit for the range considered as comfort which varies from 41 to 42 °C (Oliveira et al., 2006). Thus, it is observed that the t_{db} of 24°C provided a significant decrease in t_{clo} of the broilers ($P < 0.05$, Scott-Knott test), thus characterizing cold stress condition (Castilho et al., 2015).

For t_{db} of 27°C it is observed that the t_{clo} is within the comfort range however, significant difference ($P < 0.05$, Scott-Knott test) occurs in relation to the other temperatures of thermal stress. In the control treatment (t_{db} = 30 °C) that characterizes thermal comfort condition (Schiassi et al., 2015, Cony & Zocche, 2004), the value of the t_{clo} is within the comfort range. However, when broilers were submitted to t_{db} of 33 °C it was found no significant difference ($P < 0.05$, Scott-Knott test) in relation to the control treatment. This is due to the fact that the broilers have been able to dissipate the produced heat by the metabolism to the environment (Abreu & Abreu 2011), because this value of t_{db} is still not enough to provide significant increase of the t_{clo}.

TABLE 3. Mean and standard deviations (in parentheses) of the cloacal temperature (t_{clo}) of broilers submitted to different intensity and duration of thermal stress during the second week of life.

t_{db} (°C)	t_{clo} (°C)	Stress duration (days)	t_{clo} (°C)
24	40.5 (0.33) a	1	41.0 (0.71) a
27	41.3 (0.39) b	2	41.3 (0.63) b
30	41.8 (0.08) c	3	41.4 (0.55) b
33	41.6 (0.36) c	4	41.5 (0.47) b

Means followed by different letters differ from one another by the Scott Knott test ($P < 0.05$).

Regarding the thermal stress duration there was a significant difference ($P < 0.05$, Scott-Knott test) between the first day in relation to the others (2nd, 3rd and 4th day), which are statistically the same ($P > 0.05$, Scott-Knott test). In this way, the broilers' ability to acclimatize confirm as reported in several studies (Alves et al., 2010; Baêta & Souza, 2010; Schiassi et al., 2015; Silva & Vieira, 2010).

When applying the cluster analysis methodology on the t_{db} as a function of the t_{clo} it is observed that the classifications of t_{db} associated with the distance scale in the dendogram (Figure 2) presented similar results to those obtained by the variance analysis and the mean test by Scott-Knott at the 5% probability level.

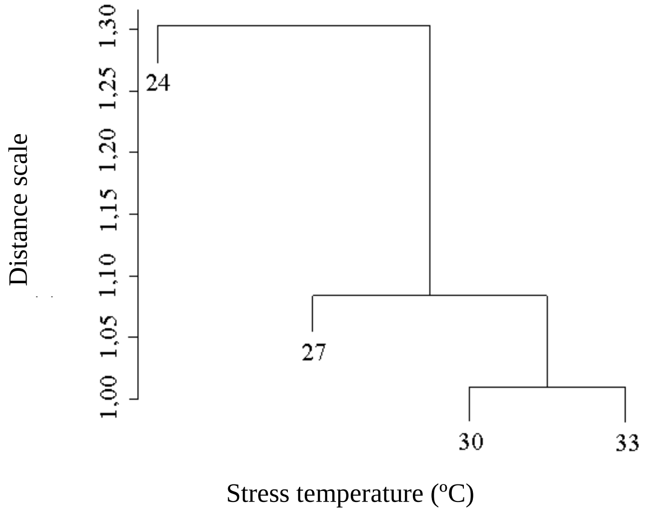

FIGURE 2. Analysis in dendrogram of air dry-bulb temperature (t_{db}) according to the cloacal temperature (t_{clo}) of broilers subjected to different intensities of stress in the second week of life.

By means of the thermographic images it was verified that the broilers average t_{sur} reduced and increased when submitted to low and high stress temperatures respectively, corroborating with the results obtained by several authors (Welker et al., 2008; Yahav et al., 2005).

The interaction between t_{db} and the thermal stress duration for the means of the t_{sur} was significant (P <0.05, F test) (Table 4). For one day of stress, it was observed significant difference (P <0.05, Scott-Knott test) for all used temperatures with the average variation of the t_{sur} being 5.0 °C.

TABLE 4. Mean and standard deviations of surface temperatures (t_{sur}) of broilers submitted to different durations of thermal stress during the second week of life.

t_{db} (°C)	**Thermal stress duration (days)**			
	1	**2**	**3**	**4**
24	30.0 (0.43) a A	31.6 (0.60) a B	31.6 (0.32) a B	30.7 (1.80) a A
27	32.0 (0.37) b A	31.0 (0.37) a A	31.2 (0.46) a A	31.4 (0.28) a A
30	34.2 (0.10) c A	33.6 (0.17) b A	33.2 (0.40) b A	33.6 (0.32) b A
33	35.0 (0.40) d A	34.1 (0.23) b B	34.0 (0,25) b B	33.6 (0.40) b B

Averages with different letters (uppercase in the row and lowercase in the column) indicate statistical differences (P <0.05) by the Scott Knott test.

For the durations of thermal stress of two, three and four days there was no significant difference (P> 0.05, Scott-Knott test) of the t_{sur} between t_{db} at 24 and 27 °C (stress due to low temperatures) and also between t_{db} at 30 °C (comfort) and 33°C (stress with high temperature). However, there was a statistical difference (P <0.05, Scott-Knott test) from t_{sur} between the two groups of t_{db} (24 °C / 27 °C and 30 °C / 33 °C).

Based on the results it can be verified that when the broilers were exposed to thermal stress at low air temperature (27 °C), in relation to comfort t_{db} (30 °C) significant difference was found (P <0.05, Scott-Knott test) for the t_{sur} in four thermal stress duration. According to Cassuce et al. (2013) the air temperature of 27 °C is comfortable in the second week of life for broilers, but the recommended comfort value in the literature for the second week is 30 °C (Schiassi et al., 2015; Cony & Zocche, 2004), and can be confirmed through the t_{clo} and t_{sur} observed in this study. However, it should be emphasized that this analysis represents only the variation of two physiological parameters without considering the zootechnical responses.

Equations for estimation of the t_{clo} and t_{sur} were adjusted as a function of t_{db} (equations 2 and 3, respectively). The adjusted equations were significant (P <0.05, F test) and showed determination coefficients (R^2) of 0.75 and 0.76, respectively. The adjusted coefficients for eqs (2) and (3) were significant (P <0.01, t test), and the standard errors of b_0 constant were 0.39 and 0.87 and for b_1 of 0.13 and 0,03, respectively.

$$t_{clo} = 37.53 + 0.13 \cdot t_{db} \quad (2)$$

$$t_{sur} = 22.30 + 0.36 \cdot t_{db} \quad (3)$$

According to eqs (2) and (3) for each degree of variation in the t_{db} occurs the modification of 0.13 °C and 0.36 °C for the t_{clo} and t_{sur}, respectively. According to Carvalho et al. (2004), the surface temperature of broilers is subject to faster alteration, since the dissipation of the blood flow occurs through the convection. This behavior can be verified through eqs (2) and (3) in which for each degree of variation, t_{sur} varies 2.77 times more than t_{clo}.

Thus, when subjected to stress at low intensities (24°C) there is reduction of 0.78 and 2.16 °C for t_{clo} and t_{sur} respectively, and when stress occurs with high intensity (33 °C) the increase is 0.39 and 1.08 °C for t_{clo} and t_{sur}, respectively, when compared to comfort temperatures (30 °C).

Considering the importance of statistical analysis for correlation equations formulation between t_{clo} as a function of t_{sur} (Nascimento, 2010), [eq. (4)] was adjusted in which R^2 was 0.75.

$$t_{clo} = 37.93 + 0.32 \cdot t_{sur} \quad (4)$$

Through the [eq. (4)] it is possible to determine the t_{clo} in a non-invasive way, through the use of infrared sensors for the measurement of the t_{sur}. Thus, it is possible to estimate t_{clo} with minimum stress for broilers, and in the usual methodology for the determination of t_{clo} it is necessary the direct contact of the thermometer with the cloaca of the broilers occurring in this way a stress factor. Equation 4 can be used in an algorithm to be shipped in microcontrollers to help the decision making regarding the activation of ventilation and evaporative cooling systems.

CONCLUSIONS

Based on the values of surface temperature (t_{sur}) and cloacal temperature (t_{clo}) it was found that the thermal comfort temperature for broilers in the second week of life is 30 °C. The acclimatization of broilers to thermal stress occurred from the second day of stress. The highest variation of the t_{clo} occurred when the broilers were submitted to low stress temperatures, and the t_{sur} varied according to the applied stress intensities. The correlation equations developed can be used to support the decision making.

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