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Assessment of Broiler Surface Temperature Variation When Exposed to Different Air Temperatures

ABSTRACT

This study was conducted to determine the effect of the air temperature variation on the mean surface temperature (MST) of 7- to 35-day-old broiler chickens using infrared thermometry to estimate MST, and to study surface temperature variation of the wings, head, legs, back and comb as affected by air temperature and broiler age. One hundred Cobb® broilers were used in the experiment. Starting on day 7, 10 birds were weekly selected at random, housed in an environmental chamber and reared under three distinct temperatures (18, 25 and 32 °C) to record their thermal profile using an infrared thermal camera. The recorded images were processed to estimate MST by selecting the whole area of the bird within the picture and comparing it with the values obtained using selected equations in literature, and to record the surface temperatures of the body parts. The MST estimated by infrared images were not statistically different ($p > 0.05$) from the values obtained by the equations. MST values significantly increased ($p < 0.05$) when the air temperature increased, but were not affected by bird age. However, age influenced the difference between MST and air temperature, which was highest on day 14. The technique of infrared thermal image analysis was useful to estimate the mean surface temperature of broiler chickens.

INTRODUCTION

Broiler production in tropical countries like Brazil faces the challenge of controlling heat stress, especially during the warmer periods of the year. Live performance is impaired when birds are reared at temperatures above their comfort zone due to reduced feed intake because dietary energy is used to maintain constant body temperature, instead of converting feed into meat (Fukayama *et al.*, 2005; Laganá *et al.*, 2007). Zhou & Yamamoto (1997) found that broiler body temperature increased three degrees Celsius (41 - 44 °C), and skin temperature increased 6 °C (37-43 °C) when exposed to heat stress (36 °C) for three hours.

Increasing sensible heat loss may promote heat tolerance in broilers, and this seems to be more beneficial than heat loss by evaporation, which may lead to dehydration. The difference between surface temperature and ambient temperature is the main parameter to determine sensible heat loss (Yahav *et al.*, 2008). Different body parts present different heat during the rearing period, and this is related to environmental air temperature and birds' feathering index (Nääs *et al.*, 2010).

Infrared cameras measure the amount of invisible heat energy emitted by surfaces and convert them into surface temperature, producing thermal images. These measuring instruments have been



on sensible heat loss (Czarick *et al.* 2007; Cangas *et al.* 2008; Yahav *et al.*, 2008).

This study aimed at evaluating the effect of different air temperatures on mean surface temperature (MST) and on the surface temperature of different body parts of 7- to 35-day-old broilers using infrared thermography and equations available in current literature (Richards, 1971; Dahlke *et al.*, 2005).

MATERIALS AND METHODS

Birds and husbandry

A group of 100 Cobb® broilers were reared in a small-scale broiler house between 1 and 35 days of age. Feed and water were offered *ad libitum*. Ten birds were weekly selected at random in the broiler house and sent to the State University of Campinas, College of Agricultural Engineering, where they were housed in environmental chambers and exposed to three levels of heat stress.

Experimental procedure

Three groups of ten birds were exposed to three air temperatures (18, 25 and 32 °C) each for at least 15 minutes before thermal images started to be recorded. Thermal images were obtained using the camera TESTO® 880 (Figure 1). Birds were tested at 7, 14, 21, 28 and 35 days of age. A completely randomized experimental design in a 5 x 3 factorial arrangement (five ages and three air temperatures) was applied, with 10 replicates per treatment, totaling 150 experimental units. Infrared thermography was used to measure broiler MST by selecting the entire area of the bird in the photo using the software Testo IIRSoft® to obtain the mean temperature of the selected area (Figure 1). The adopted emissivity of the broiler surface was 0.95, as proposed by Cangas *et al.* (2008).

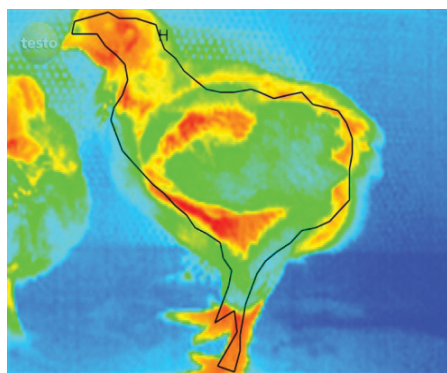


Figure 1 Sample selection of the nominated area of a broiler to

The MST results obtained with the thermal images were compared with the equations proposed by Richards (1971) (Eq. 1) and by Dahlke *et al.* (2005) (Eq. 2) to estimate broiler MST, as follows:

$$MST_1 = (0.12 TW) + (0.03 TH) + (0.15 TP) + (0.70 TB) \quad (1)$$

$$MST_2 = (0.03 TC) + (0.70 TB) + (0.12 TA) + (0.06 TH) + (0.09 TL) \quad (2)$$

Where: MST = mean surface temperature (°C) TW = wing surface temperature (°C), TH = head surface temperature (°C), TL = leg surface temperature (°C), TB = back surface temperature (°C), TC = comb surface temperature (°C).

The surface temperatures of each body part of the birds were estimated using their infrared thermal images, as suggested by Nääs *et al.* (2010).

Using the record of the birds' mean surface temperature, the difference between MST and air temperature (temperature rise, °C) was calculated, and this difference was analyzed for each tested age. MST data obtained by the use of infrared thermography were compared by Student's t-test at 95% confidence level, and to the results obtained with the equations proposed by Richards (1971) and Dahlke *et al.* (2005).

Mean surface temperature variations of the broilers' body parts, as a function of age and air temperature, were submitted to analysis of variance at 95% confidence level. When differences were significant, means were compared by the test of Tukey (at 95% confidence level), using the statistical software MINITAB® 15.

RESULTS AND DISCUSSION

Mean surface temperatures obtained by infrared thermal imaging were not different by the Student's t-test ($p > 0.05$), as compared to the estimates obtained with the equations proposed by Richards (1971) and Dahlke *et al.* (2005). High positive correlations of 0.985 and 0.986, respectively, were obtained for both comparisons (Table 1). According to Cangas *et al.* (2008), it is important to have efficient environmental control, more efficient energy use, and better design of broiler houses in order to obtain more accurate information on bird surface temperature for better understanding heat transfer circumstances.

There was no difference ($p > 0.05$) between the MST results obtained using the estimation equations



obtained thermal imaging (TI) relative to bird age (Figure 2).

Table 1 - Results of Student's t-test and correlation between MST values obtained by thermal imaging and their estimation using Eq. 1 and Eq. 2 in broilers.

	N	Average	p - value	Pearson's correlation
Thermal imaging (TI)	150	32.2 ± 4.0	0.744	0.985
Dalhke (2005)	150	32.0 ± 5.0		
Thermal imaging (TI)	150	32.2 ± 4.0	0.975	0.986
Richards (1971)	150	32.2 ± 4.8		

N= number of broilers assessed during trial.

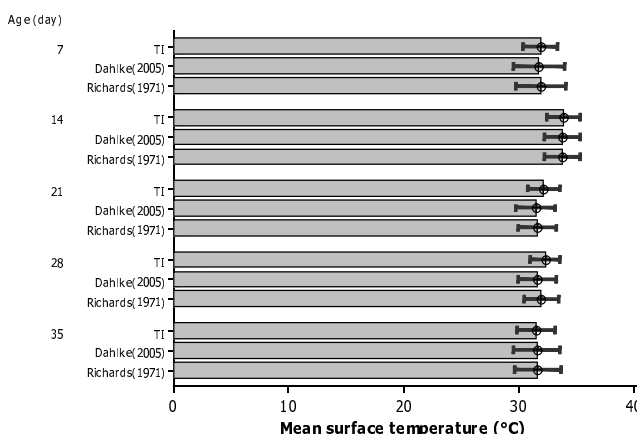


Figure 2 - Variation of the estimated surface temperature using infrared thermal imaging (TI) and the equations of Dalhke *et al.* (2005) and Richards (1971) as a function of bird age.

Age did not influence mean surface temperature ($p = 0.17$). The lowest MST was found in 35-day-old birds (Table 2), which is consistent with the results of Tessier *et al.* (2003), who reported that older birds (35 days of age) presented the lowest mean surface temperatures, probably due to their thick feather coverage. Those authors mention that birds' core temperature is

normally constant (41 °C), but it decreases over the peripheral zone. However, in the present study, MST differences as a function of age were not significant, and the highest MST was observed in 14-day-old birds.

The MST of the birds exposed to different environmental temperatures were different ($p = 0.01$), with increasing MST as air temperature increased. According to Cangas *et al.* (2008), surface vascularization is directly related to the increase in MST, which is directly affected by air temperature (Table 2). Thermal comfort is very important during broiler rearing as the maintenance of body temperature is essential to promote good performance. In addition, optimal ideal environment temperatures change during the grow-out period, and therefore, the knowledge on broilers' surface temperatures may contribute to assess their thermal comfort.

The regression analysis of MST data as a function of age resulted in a quadratic equation (Eq. 3), with the highest temperature obtained when birds were 14 days of age (\hat{y}_1), probably due to their thinner body feathering. When MST data were analyzed as a function of air temperature, a linear equation was obtained (\hat{y}_2 , Eq. 4), showing that bird surface temperature increased with air temperature (T_{air}).

$$\hat{y}_1 = 31.18 + 1.39age - 0.27 age^2; (R^2 = 0.80) \quad (3)$$

$$\hat{y}_2 = 16.4 + 0.635 T_{air}; (R^2 = 0.84) \quad (4)$$

Equation 5 (\hat{y}_3) was obtained using multivariate analysis and it shows the influence of air temperature on mean surface temperature (MST). The trend of decreasing birds MST as a function of age is due to an increase in the feathering index of the different body parts, acting as an insulating layer (Garcia *et al.*, 2002).

$$\hat{y}_3 = 17.1 + 0.635 T_{air} - 0.0326 age, (R^2 = 0.87) \quad (5)$$

Table 2 - Change in mean surface temperature (MST) as measured by infrared thermography according to broiler age and air temperature.

Age (day)	Air temperature (°C)			Average ¹	p - value
	18	25	32		
7	27.3abC ± 1.0	31.5bB ± 0.6	36.8abA ± 0.5	31.9 ± 4.0	0.01
14	28.7aC ± 1.0	35.4aB ± 0.8	37.5aA ± 1.0	33.9 ± 4.0	
21	28.6aC ± 1.5	31.1bB ± 1.5	36.8abA ± 0.4	32.2 ± 3.7	
28	28.6aC ± 1.6	31.9bB ± 1.1	36.3bcA ± 0.7	32.3 ± 3.4	
35	26.4bC ± 0.8	31.3bB ± 0.5	36.8abA ± 0.3	31.5 ± 4.4	
mean ²	27.9C ± 1.5	32.2B ± 1.9	36.8A ± 0.7		
p - value				0.17	



Air velocity is the parameter that most strongly influences sensible heat loss and contributes to the acclimation capacity of broilers, consequently enhancing bird capacity to regulate its body temperature when exposed to heat stress (Yahav *et al.*, 2005). In the present study, air velocity was kept at zero to test the variation in bird surface temperature without the influence of this specific variable. Air relative humidity recorded was $76 \pm 3\%$ at 18°C , $68 \pm 2\%$ at 25°C , and $65 \pm 3\%$ at 32°C air temperature, inside the environmentally-controlled chamber.

According to ANOVA results (Figure 3), temperature rise (difference between MST and air temperature) was influenced by bird age ($p=0.03$). The greatest difference occurred when birds were 14 days old ($8.8 \pm 2.5^\circ\text{C}$), but it was not different from the temperature rise at 28 days ($7.3 \pm 2.9^\circ\text{C}$). On days 7, 21 and 35, temperature rises of $6.9 \pm 2.0^\circ\text{C}$, $7.2 \pm 2.8^\circ\text{C}$ and $6.5 \pm 1.6^\circ\text{C}$, respectively, were observed, and these values were not different from the temperature rise that occurred on day 28. The difference in surface temperature rise as a function of broiler age was reported by Cangas *et al.* (2008), who found the largest difference on day 28 and suggested that it was probably due to feather molting occurring at that age.

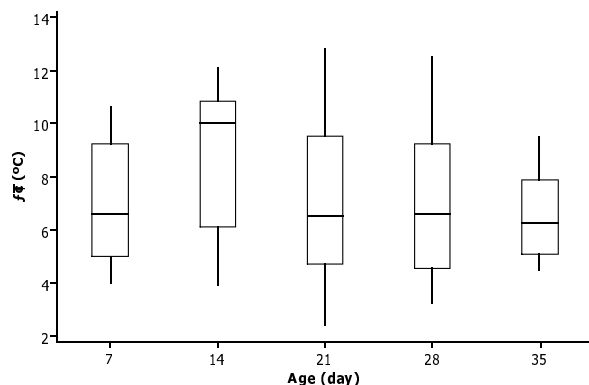


Figure 3 - Boxplot of the effect of age on the difference between broiler mean surface temperature and air temperature ($^\circ\text{C}$).

Although the results indicate that the difference between MST and air temperature were similar on days 14 and 28, the highest average difference was verified on 14 day as compared to the other evaluated ages. This was probably due to the development of thermoregulation by the birds, increasing their heat loss capacity through peripheral blood circulation.

Wings, head, legs, back and comb surface temperature significantly rose ($p < 0.05$) with the

between air and surface temperatures was found in the legs (14.8°C) when air temperature was between 18 and 32°C (Figure 4). This result is consistent with the findings of Nääs *et al.* (2010), who found that featherless body parts increase surface temperature gradient, when air temperature changes.

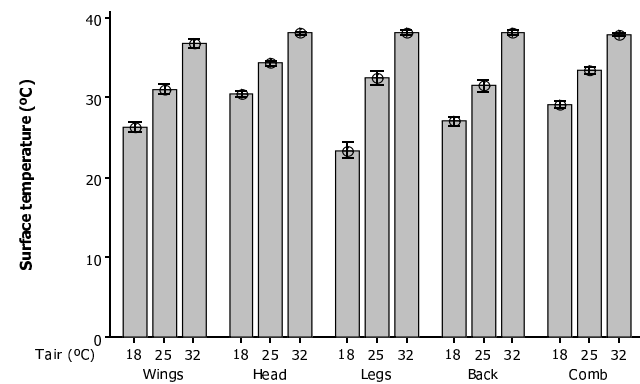


Figure 4 - Variation body parts surface temperature of broilers as a function of air temperature (Tair).

The lowest MST in broilers was detected at an air temperature of 18°C , which was probably due to peripheral vasoconstriction because blood flow to the body surface is reduced to prevent heat loss. This vasoconstriction was more pronounced in the featherless areas, such as the legs and the comb. Only leg MST was significantly influenced ($p\text{-value} < 0.05$) by bird age, possibly to the above mentioned mechanism of vasoconstriction that decreases blood flow in featherless areas (Table 3). This effect of age on the mean surface temperature was also observed by Cangas *et al.* (2008) in the wings and back of 3- to 37-day-old broilers.

The results obtained in the present study show that body surface temperature can be evaluated through the direct measurement using infrared thermographic cameras or by both equations previously mentioned (Eq 1 and Eq 2).

CONCLUSIONS

Infrared thermographic cameras are useful tools to measure broiler surface temperature and can be used to evaluate their mean surface temperature. Under the specific conditions of the present experiment, broiler surface temperature varied as a function of the air temperature of the rearing environment, but was not affected by broiler age.



Table 3 - Variation of body parts surface temperature as a function of bird age.

Age	Surface temperature (°C)				
	Wing	Head	Leg	Back	Comb
7	32.2 ± 5.9	33.7 ± 4.3	30.0 ^{ab} ± 7.7	31.9 ± 5.8	32.9 ± 4.4
14	32.3 ± 3.9	34.4 ± 3.6	33.6 ^a ± 4.5	34.0 ± 4.2	33.8 ± 3.8
21	31.1 ± 4.2	33.6 ± 3.2	31.1 ^{ab} ± 6.6	31.5 ± 4.5	32.7 ± 3.8
28	30.7 ± 3.6	35.0 ± 2.5	28.6 ^b ± 7.6	32.2 ± 4.0	34.1 ± 3.1
35	30.4 ± 5.6	34.6 ± 3.0	33.0 ^a ± 5.6	31.3 ± 5.7	33.7 ± 3.8
p - value	0.401	0.392	0.019*	0.225	0.511

*Significant difference by the F test. Means followed by different small letters in the same column are significantly different by the Tukey test ($p < 0.05$).

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