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Surface Temperature Distribution in Broiler Houses

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ABSTRACT

In the Brazilian meat production scenario broiler production is the most dynamic segment. Despite of the knowledge generated in the poultry production chain, there are still important gaps on Brazilian rearing conditions as housing is different from other countries. This research study aimed at analyzing the variation in bird skin surface as function of heat distribution inside broiler houses. A broiler house was virtually divided into nine sectors and measurements were made during the first four weeks of the grow-out in a commercial broiler farm in the region of Rio Claro, São Paulo, Brazil. Rearing ambient temperature and relative humidity, as well as light intensity and air velocity, were recorded in the geometric center of each virtual sector to evaluate the homogeneity of these parameters. Broiler surface temperatures were recorded using infrared thermography. Differences both in surface temperature (Ts) and dry bulb temperature (DBT) were significant ($p<0.05$) as a function of week of rearing. Ts was different between the first and fourth weeks ($p<0.05$) in both flocks. Results showed important variations in rearing environment parameters (temperature and relative humidity) and in skin surface temperature as a function of week and house sector. Air velocity data were outside the limits in the first and third weeks in several sectors. Average light intensity values presented low variation relative to week and house sector. The obtained values were outside the recommended ranges, indicating that broilers suffered thermal distress. This study points out the need to record rearing environment data in order to provide better environmental control during broiler grow-out.

INTRODUCTION

Broiler production is an important item of Brazilian exports, and it is becoming increasingly dynamic. The concept of thermal comfort is related to the birds' rearing environment, especially in open-sided or curtain-sided poultry houses. Exposure to heat stress impairs live production as it reduces the bird's ability to exchange sensible heat with its surroundings (Morrow, 2001; Moura, 2001; Abu-Dieyeh *et al.*, 2006). Increase in air velocity by the use of fans may alleviate heat stress (Yahav *et al.*, 2001 and 2004) as it increases heat loss by convection.

Due to the thick insulation provided by the feather coat on most of the body surface, broiler sensible heat loss is more efficient in featherless body areas, where blood flow increases when birds are exposed to heat stress. Broilers exposed to heat stress significantly decreased blood flow to heat-exchange organs and skin surface (Borges *et al.*, 2003; Altan *et al.*, 2003), which results in lower sensible heat loss from the extremities and featherless areas, increasing metabolic expenditure to regulate body

The use of infrared thermography allows identifying spots with different radiant temperatures, and it is a valuable tool for recognizing physiological abnormalities in humans and animals. Surface temperature can be measured from a distance with high precision, especially on animal coats with low heat capacities, and it does not disturb the animals (Richards, 1971; McCafferty *et al*., 1998).

This study aimed at analyzing broiler surface temperature variation as function of the ambient data fluctuation during the first four weeks of rearing of two different flocks.

MATERIAL AND METHODS

The study was carried out in a commercial broiler farm located in the region of Rio Claro, state of São Paulo (longitude 47°37'52'' W and latitude 22°24'54'' S), Brazil, using two flocks between one and 28 days of age. Data was recorded and analyzed weekly on days 7, 14, 21, and 28 of the grow-out during the periods of March to April 2009 (flock 1 with 20,200 birds), and May to June 2009 (flock 2, with 20,000 birds).

The broiler house was 12m wide, 120m long and 3m high, with concrete poles at every 8m in the length. The roof was made of fibercement tiles, and had polyethylene canvas ceiling. Tunnel ventilation was used for air cooling and exchange using exhaustion fans placed on the west of the building; and the inlet with evaporative cooling pads were placed on the east side. The side walls were made of blue polyethylene curtains on the inside and white on the outside. Rice hulls and wood shavings were used as litter material. Brooding during the starter phase was provided by natural gas heaters.

The broiler house was virtually divided into nine sectors, which were modified as birds grew in order to properly register the variation in ambient data (Figure 1). Environmental variables (dry bulb temperature-DBT, and relative humidity-RH) were recorded using the thermal stress monitor Questemp® 34 in each geometrical center of the nine sectors.

In the same place ambient data and surface temperature of broilers were recorded using infrared thermography (Termovisor Testo® 880-St). Air velocity was recorded using a digital thermo hygro-anemometer and light intensity was recorded using the digital luxmeter (HOMIS®), as suggested by Jones *et al*. (2005) and Bessei (2006), respectively.

Total sensible heat loss (Q) was calculated (Eq.

convection (QC), as suggested by Yahav *et al*. (2004) and Van Brecht *et al*. (2005), respectively (Eq. 2 and 3).

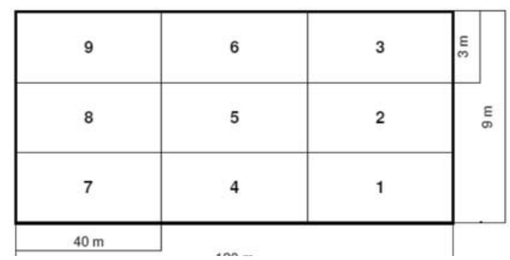

Figure 1 - Scheme of the broiler house, showing the sectors where data were collected.

$$Q = Q_R + Q_C \quad \text{Eq.1}$$

$$Q_R = e\ \sigma\ A\ (T_S{}^4 - T_{air}{}^4) \quad \text{Eq.2}$$

$$Q_C = h\ A\ (T_S - T_{air}) \quad \text{Eq.3}$$

$$h = 0.336\ \ 4.184\ \ (1.46 + \sqrt{V_{air}} - 100) \quad \text{Eq.4}$$

Where Q = total sensible heat (W), e = bird emissivity (0.95), σ = Stefan-Boltzman constant ($5.67m^{-2} \times 10^{-8}$, $W\ m^{-2}\ K^{-4}$), A = bird surface area (m^2), and h= heat transfer coefficient given by Eq. 4 (15 $W\ m^{-2}$ C), Vair= air velocity, Qr = heat loss by radiation (W), Qc = heat loss by convection (W), ε = emissivity of biological tissue, Ts = bird's surface temperature (C), and Tair = air temperature (C). The area (A, m^2) in Eq. 2 and Eq. 3 was estimated as the average area of a spherical form exposed to convective and radiant heat transfer. The software Surfer® version 8.02 was used to map surface temperature data (Ts, °C) and ambient dry bulb temperature (DBT, °C).

Data were analyzed using one-way ANOVA and 95% statistical significance level was adopted. Paired Tukey test was used to compare the results.

RESULTS AND DISCUSSION

Table 1 presents broiler surface temperature (Ts, °C) and ambient dry bulb temperature (DBT, °C) data according to the studied sectors.

Differences were significant ($p < 0.05$) both in surface temperature (Ts) and dry bulb temperature (DBT) between weeks, and Ts results were significantly different between the first and fourth week ($p < 0.05$) in both flocks (Table 2). This results were expected as

Table 1 - Broiler surface temperature (Ts, °C) and ambient dry bulb temperature (DBT, °C) per house sector and grow-out week in flocks 1 and 2.

Flock Sector	Mean temperature variation per grow-out week															
	Ts1		DBT1		Ts2		DBT 2		Ts3		DBT3		Ts4		DBT4	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	25.5	34.2	25.9	24.5	24.7	31.3	27.2	21.5	24.8	30.4	25.7	20.6	24.6	29.0	24.8	19.4
2	27.2	34.5	26.4	27.2	27.5	30.7	28.0	22.7	24.8	32.6	25.5	20.7	27.1	30.5	25.2	20.2
3	26.3	34.1	26.8	27.3	26.4	30.7	29.3	23.4	26.0	31.6	25.9	22.3	26.0	30.4	26.1	20.7
4	28.4	32.8	27.4	23.3	27.5	31.1	27.6	23.0	26.1	32.6	27.2	23.3	25.6	28.8	28.0	22.3
5	28.3	34.8	27.9	27.9	29.2	32.6	29.0	24.6	26.9	35.4	27.3	23.0	26.1	33.0	28.2	23.0
6	26.0	36.5	27.9	28.2	29.5	32.5	29.8	25.5	27.5	32.5	27.3	24.1	24.1	31.6	26.7	24.1
7	27.0	34.4	28.2	24.5	27.4	33.1	27.3	23.9	26.5	31.9	27.5	23.7	25.6	30.9	27.6	23.6
8	26.4	35.3	27.7	26.4	28.0	32.8	28.5	24.6	26.2	31.1	27.4	23.8	25.8	32.1	27.6	23.6
9	26.2	35.5	27.9	28.2	28.0	33.3	29.5	25.6	27.3	33.5	27.3	24.7	25.6	32.6	27.4	23.8
Ave week^{-1}	26.81	34.7	27.34	26.4	27.58	32.0	28.47	23.9	26.23	32.4	26.79	22.9	25.61	31.0	26.84	22.3
Δt	0.53	8.3			0.89	8.1			0.56	9.5			1.23	8.7		

Δt= TBS-Ts. DBT- dry bulb temperature. Ts-surface temperature.

exposure and DBT variation was similar in the second to third and fourth week ($p<0.05$). Temperature difference between Ts and DBT varied among weeks. DBT and Ts distributions were also different among house sectors (Figures 2 and 3).

Because sensible heat is directly related to temperature differences (Yahav *et al*., 2001 and 2004), excessive heat loss occurred during the first weeks of the grow-out. According to Yahav *et al*. (2004) the gradient between ambient and bird surface temperature determines sensible heat exchange, which is used as an input in the calculation of forced ventilation systems.

Table 2 - Birds surface temperature during the four grow-out weeks of growth in flocks 1 and 2.

Week	Flock surface temperature (Ts, °C)	
	Flock 1	Flock 2
1	35.9 ± 2.0a	34.7 ± 1.8a
2	35.2 ± 1.6ab	32.0 ± 2.2ab
3	33.7 ± 2.5ab	32.4 ± 3.0ab
4	33.0 ± 2.6b	31.0 ± 3.0b
Average	34.5 ± 2.5	32.5 ± 3.2

Tukey's test (95%).

Surface temperature was higher in flock 2 (Table 2). The calculation of Pearson's correlation between ambient dry bulb temperature and broiler surface temperature response showed moderate correlation (0.44, for flock 2 data) between bird surface temperature (Ts) and the ambient temperature (DBT). This result indicates that rearing ambient conditions were not favorable to broiler growth, according to Altan *et al*. (2003) and Borges *et al*. (2003). Table 3 shows that there was no effect on broiler performance and feed conversion. Mortality was higher in flock 1 (5.6%) as compared to flock 2 (3.5%) probably due to the number of reared birds.

Table 3 – Mean broiler performance results.

	Flock surface temperature (Ts, °C)	
	Flock 1	Flock 2
Number of reared birds	20,200	20,000
Mortality (%)	5.6	3.5
Daily weight gain (g)	61.6	60.58
Feed conversion ratio	1.7	1.7

This indicates birds were probably using extra energy to maintain their body temperature, especially in flock 2, as Δt[*1] values significantly increased during rearing (Bootje & Harrison, 1985; Chepete *et al*., 2005).

Recorded rearing ambient data were compared to the recommended values in literature (Albright, 1990; Moura, 2001), and the results (Table 4) indicate some degree of bird distress, as the recorded values were different from the optimal recommendations, which may explain the worse final performance indexes (Bootje & Harrison, 1985; Macari *et al*., 1998; Owada *et al*., 2007). Sevegnani (1997) pointed out the negative effects on broiler production when the housing conditions do not provide adequate thermal environment or air exchange, causing thermal discomfort in the birds.

The DBT values recorded in different house sectors during the studied grow-out weeks (Table 4) were higher than those recommended in current literature, which may have negatively affected broiler growth and performance (Chepete *et al*., 2005). Research

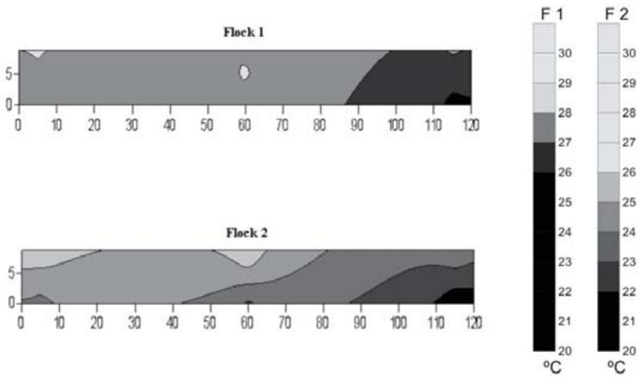

Figure 2 - Dry bulb temperature distribution inside the poultry house during the grow-out of flocks 1 and 2.

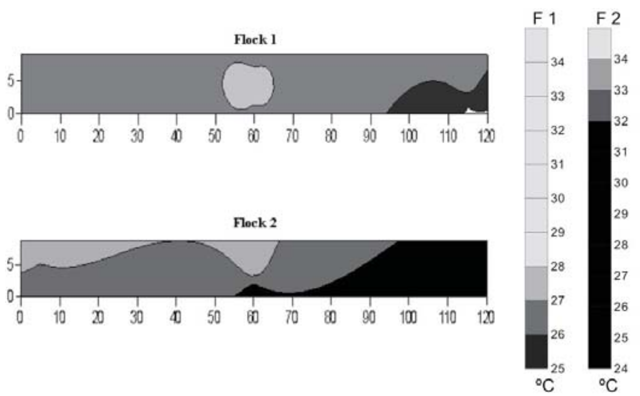

Figure 3 - Surface temperature distribution inside the poultry house during the grow-out of flocks 1 and 2.

temperature may cause significant broiler performance losses (Ain Baziz *et al*., 1996) and increase both in feed and water consumption attempting to maintain stable body core temperature (Smith & Teeter, 1993).

Relative humidity values were within acceptable range (50 - 70%) in flock 1 and 2, but above the recommended levels (Table 4).

Air velocity data were beyond the recommended threshold in the first and third week in several house sectors. According to Moura (2001), this may have negatively impact performance. Tao & Xin (2003) recommend air velocities between 0.2 and 1.2 m s^{-1} inside broiler houses and Sevegnani *et al*. (2005) proposes values between 0.3 and 1.0 m s^{-1} for adult birds. However, lower limits are adequate to chicks during their first weeks of life. According to Yahav *et al*. (2001), sensible heat loss by broilers exposed to a certain range of air velocities (0.8 – 2.5 m s^{-1}) may be significantly different, although sensible heat loss by convection is higher when the air velocity increases.

Average light intensity values showed low variation as a function of week and house sector. Relative humidity, air velocity and light intensity results are shown in Table 5. The average difference in surface temperature between flocks 1 and 2 was nearly 3 °C (34.5 ± 2.5 in flock 1 and 32.5 ± 3.2 in flock 2).

The assessment of heat loss by radiation (Qr), convection (Qc), and total sensible heat loss (Qt) of both flocks are shown in Figure 4. There was a variation

temperature are usually proportional to increases in the ambient temperature. Boone & Hughes (1971) found that pullet body temperature is soundly regulated when ambient temperature is around 30°C; however, when DBT increases in 5°C, birds present a significant reduction in their capacity to exchange sensible and latent heat, leading to low feed intake, and eventually, to death. This variation in surface

Table 5 - Relative humidity, air velocity and light intensity (mean ± standard deviation) recorded during the four studied grow-out weeks in the two flocks.

	Flock	Week			
		1	2	3	4
Relative humidity (%)	1	67.1 ± 5.4	66.6 ± 4.6	67.1 ± 6.1	56.5 ± 3.4
	2	61.4 ± 5.1	62.0 ± 5.2	60.0 ± 3.0	64.0 ± 6.3
Air velocity (m s^{-1})	1	0.28 ± 0.2	0.79 ± 0.3	1.1 ± 0.5	2.0 ± 0.4
	2	0.25 ± 0.2	0.5 ± 0.2	0.5 ± 0.3	0.7 ± 0.3
Light intensity (lx)	1	7.3 ± 3.2	6.9 ± 1.9	6.6 ± 2.0	7.0 ± 2.6
	2	11.7 ± 2.4	8.2 ± 2.2	7.6 ± 2.0	5.1 ± 1.3

Table 4 - Rearing environment parameters that presented values beyond the threshold according grow-out week and house sector.

	Week of growth			
Rearing ambient data	**1**	**2**	**3**	**4**
Temperature (DBT)	7	3,5,6 8 and 9		5
Relative humidity (RH)				
Air velocity (Vair)	1,2,3,4,5,6,7,8, and 9		1,3,8 and 9	
Rearing ambient data	**1**	**2**	**3**	**4**
Temperature (DBT)	6 and 9	1,2,3 and 4		1
Relative humidity (RH)	7 and 8	7	1,2,3,4,5,6,7, and 9	1

in the heat exchange during the studied weeks, and heat loss was higher in flock 2 than in flock 1. When broilers are exposed to harsh rearing environments, the gradient between average surface temperature (35°C) and mean ambient temperature (32°C) was low, which hinders sensible heat or radiation. In this case, panting is virtually the only way birds effectively loose heat, and this physiological response demands high energy expenditure (Furlan & Macari, 2002). However, when relative humidity is high (>70%), this form of latent heat loss becomes ineffective (Lasiewski *et al*., 1966).

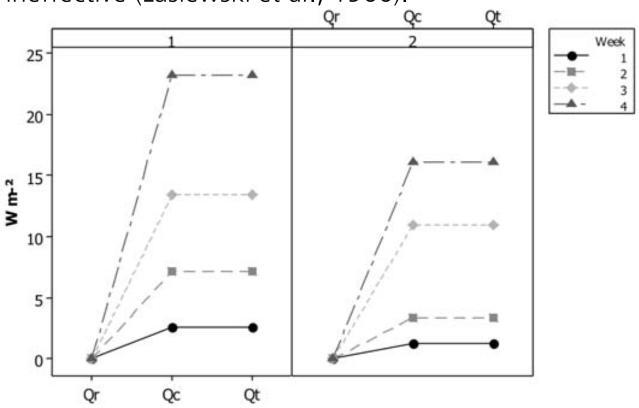

Figure 4 - Sensible heat loss by radiation (Qr), convection (Qc) and total (Qt) estimated per bird in both flocks.

CONCLUSIONS

The variation in broilers' rearing environment by sector may have influenced their surface temperature. Rearing environmental data were beyond the recommended thresholds for adequate broiler performance. This study indicates the need to properly record environmental data of the rearing environment in order to support better environmental control during broiler grow-out.

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