Infrared Thermography Applied to the Evaluation of Metabolic Heat Loss of Chicks Fed with Different Energy Densities

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ABSTRACT

Brazil must comply with international quality standards and animal welfare requirements in order to maintain its position as world's largest exporter of poultry meat. With the scenario of global climate change there is the forecast of occurrence of extreme events with characteristics of both excess cold and heat for several regions of the country. This study aimed to evaluate the effectiveness of using images of infrared thermography to evaluate the loss of sensible heat in young broilers fed different dietary energy levels. Twenty birds were reared in a house with appropriate brooding using infrared lamps. Birds were distributed in a completely randomized experimental into two treatments: T1 (control diet with 2950 kcal ME/kg^{-1}), and T2 (high-energy diet with 3950 kcal ME/kg^{-1}). Infrared thermographic images of the birds were recorded for four consecutive days. One bird was randomly chosen per treatment, and had special images taken and analyzed. Average surface temperature of the body area was calculated using the surface temperature recorded at 100 spots (50 at the front and 50 at the lateral side of the bird's body). Mean surface temperature of the flock was calculated recording 100 spots on the group of birds. Total radiant heat loss was calculated based on the average data of surface temperature. The results indicated that the young broilers fed the high-energy diet presented a metabolic energy loss equivalent to 0.64 kcal h^{-1}, while the birds fed with the control diet lost 2.18 kcal h^{-1}. This finding confirms that oil supplementation to the diet reduces bird heat loss. The infrared camera was able to record young broilers' surface temperature variation when birds were fed diets with different energy contents.

INTRODUCTION

Brazil produced almost 11 million tons of chicken meat in 2009, out of which 70% was exported, making it the leading poultry exporter in the world (UBA, 2009). In order to keep this position, the Brazilian production chain must make constant innovations to meet international quality standard requirements. In addition, the world's largest chicken meat importers have set deadlines for the compliance of requirements for intensive production systems, including those related to housing environment and animal welfare.

When the housing environment not within the thermoneutral zone, metabolic heat dissipation of poultry changes. The thermal tolerance of broilers varies according to age and weight. The thermal comfort zone of 1 to 7-d-old broilers is around 31-33 °C, and it is reduced to 21-23 °C when they are 35 to 42 days old, considering that air relative humidity is between 65 and 70% (Furlan & Macari, 2002). The main effects of exposure to excessive cold or heat is high flock mortality and changes in feed intake, both of which have undesirable economic

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consequences (Rutz, 1994). One of the strategies adopted to overcome the problem of reduced feed intake is to increase dietary energy density by replacing carbohydrates for fat. The use of fat is justified by the fact that it presents lower heat increment as compared to other nutrients (Ribeiro & Laganá, 2002).

Global climate change has increased the frequency of extreme weather events (IPCC, 2010), and it is necessary to know the optimal ranges of environmental variables to provide proper housing environment to poultry. Infrared thermography is a recent technology used to evaluate housing thermal conditions and their influence on the wellbeing of animals. This technology has been efficiently used to monitor the metabolic activity of domestic and wild animals by recording the surface temperature and by quantitatively and qualitatively evaluating heat flow (Klir et al., 1988; Klir & Heath, 1992; Phillips & Sanborn, 1994; McCafferty et al., 1998; Phillips & Heath, 2001). This technique has the advantage of being non-invasive and non-destructive (Eddy, 2001).

The aim of this study was to record radiant heat exchange of young broilers fed diets containing different energy levels, and to evaluate the effectiveness of an infrared thermography camera to record broiler metabolic activity by calculating its surface temperature.

MATERIALS AND METHODS

The experiment was carried out at the Grande Dourados Federal University (UFGD), Dourados, MS, Brazil, located at 430m altitude, 22°13'16"S latitude and 54°48'20"W longitude. In this region, the summer is hot and humid, with average minimum temperature of 20±1 °C, and the winter is cold and dry, with average minimum temperature of 14.3±1 °C.

Birds and management

Twenty male Ross® broilers were reared from 1-7 days of age in an experimental broiler house (50m long, 10m wide and 3m high) divided into 56 pens of 4.5m² each, with a central brooding circle of 2.5m diameter. Houses were equipped with double curtains to control excessive wind and to keep internal temperature close to the thermoneutral zone. Brooding was done using 250W infrared lamps in each circle within each pen. Artificial lighting was provided by 40W bulbs during 24h during the entire experimental period, resulting in an average light exposure of 22lx. Water was offered ad libitum in bell drinkers and feed in tube feeders. Environmental data were collected in the database

of Embrapa (2010) and house and brooding circle temperatures were recorded in the geometric center of the pens. Diets were formulated on corn and soybean meal basis to supply birds' nutritional requirements as proposed by Rostagno et al. (2005), except for energy intake, which varied according to treatments. Increasing dietary energy content was obtained by the supplementation of soybean oil.

Experimental design and statistical analysis

Birds were distributed in a completely randomized experimental design into two treatments:
T1 – control diet with 2950 kcal EM kg^{-1};
T2 – high-energy diet with 3950 kcal EM kg^{-1};

Data were submitted to analysis of variance and means were compared by the test of Tukey at 95% probability level using the statistical program SAS (2001).
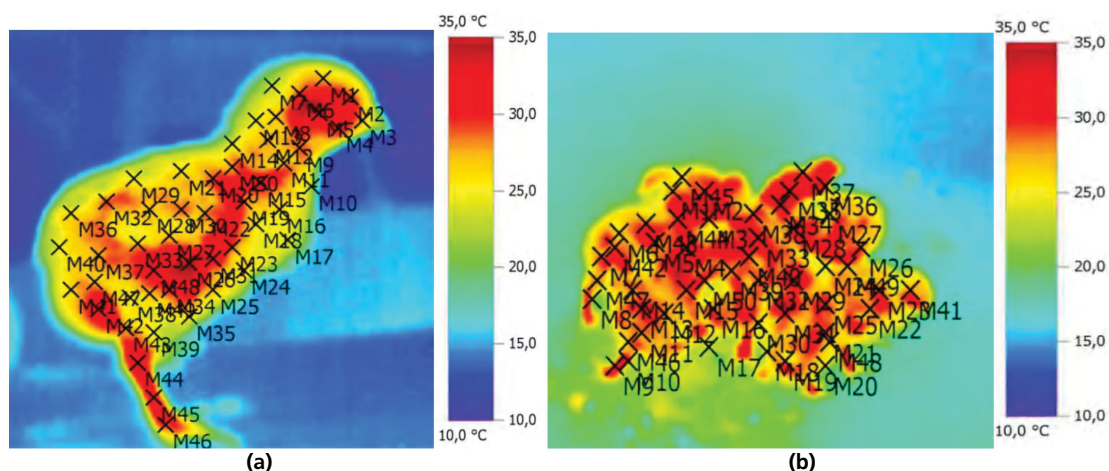
Estimation of thermal load

After two days of adaptation to the experimental diets, infrared thermal images of the birds were taken using an infrared camera (Testo® 880), with an accuracy of ± 0.1 °C and 7.5 to 13mM infrared spectrum range, during four consecutive days, always at 15h:00min. In addition to flock images, one bird per treatment was randomly chosen to record infrared thermal images of its body in order to determine its surface temperature. A coefficient of emissivity of 0.86 was used for the entire body surface of the bird (Nääs et al., 2010). Average surface temperature and standard deviation of body surface area were calculated using the temperature of 100 randomly-selected spots in the infrared thermographic image (50 in the front and 50 in the lateral side of the bird's body) and 100 spots of the entire flock (Figure 1).

Using the infrared thermographic images, bird heat loss by radiation (Qr) was calculated using Equation 1 (Meijerhof & Van Beek, 1993; Yahav et al., 2004):

$$Qr = \varepsilon \, \sigma \, A \, (Ts^4 - Ta^4) \qquad \qquad \text{Eq. 1}$$

where: Qr = heat loss by radiation (W); !ε = emissivity of biologic tissue (0.86); σ = Stefan Boltzmann Constant (5.67 10^{-8} W m^{-2} K^{-4}); A = bird surface area (m²); Ts = bird surface temperature (℃), and Ta = air temperature (℃).

Bird surface area was calculated using data from the image shapes (Figures 2a and b) of the following parts (in 3D): head (sphere), body (oval) and leg (side wall of cylinder), as indicated by Neves et al. (2009).

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Figure 1 - Spots where surface temperature was collected in thermographic images of individual broilers (a) and of the flock (b).
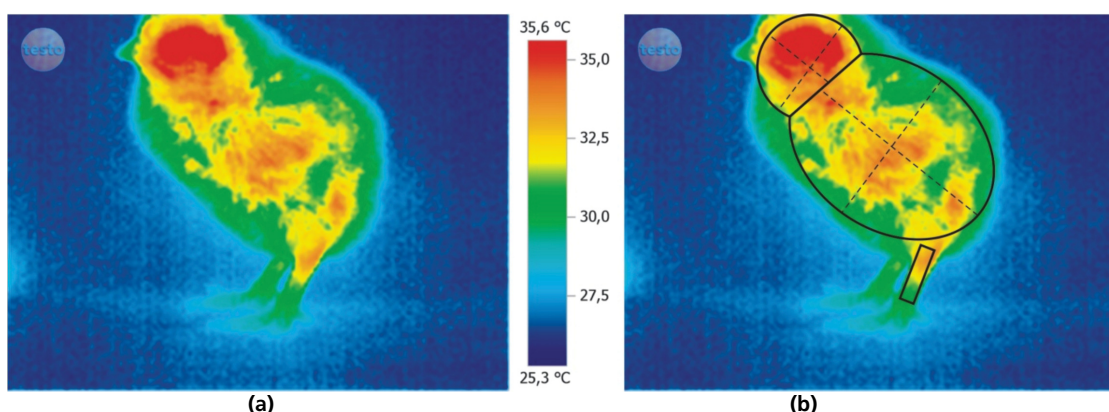
Figure 2 - Broiler infrared thermographic image (a), and the diagram used to process bird body surface area (b). Source: Neves *et al*. (2009).

Air dry temperature was recorded using a digital thermometer, and wet bulb temperature was calculated applying the program Psicrom® (Roriz, 2003), using records of relative humidity and temperature data collected from the database of Embrapa (2010).

RESULTS AND DISCUSSION

During the experiment, environmental temperature ranged between 8.4 and 9.8 °C and the recorded relative humidity was between 63% and 95% (Table 1). Average temperature below the brooder was 27 °C. According to Nicholson (2004), the recommended temperature for broilers during brooding is 32.0 and 35.0 °C, which was not achieved due to the severe cold weather that occurred during the experiment.

Although the advantage of oil addition to the diet is significant in periods of high ambient temperature (Baião & Lara, 2005; Simsek *et al*., 2009) the main objective of this study was to assess the efficiency of an infrared thermographic camera to detect variations in metabolic heat production as a function of dietary energy, independently of weather conditions. The higher dietary energy level of the diet containing soybean oil resulted in lower metabolic heat production, as demonstrated by the difference between treatments in mean surface temperature of individual birds (p <0.02) and of the entire flock (p <0.01, Table 2).

Table 1 - Outside air temperature (TO), air temperature inside the pen (TI) and bird surface temperature (TS).

Day of data recording	Temperature (°C)		
	TO	TI	TS
1	9.3	16	27
2	9.8	14.5	27
3	8.4	14.5	27
4	8.4	14	27

When evaluated separately from the flock, individual surface temperature was lower and independent of dietary energy level, suggesting that the clustering of birds allowed the reduction of radiant heat loss, (measured by the thermographic camera (Shinder *et al*. 2007; Moura *et al.*, 2008).

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Table 2 - Surface temperature of flocks and individual broilers fed diets with different energy levels.

	T1	T2	p-value	CV (%)
Flock	29.00a	27.97b	0.0001	9.68
Individual	27.33a	26.71b	0.0219	12.29
Mean	28.17	27.34		

T1 = 2950kcal ME/kg, T2 = 3950kcal ME/kg. Means followed by different letters are different by the test of Tukey (p-value < 0.05).

Considering the average environmental temperature of 27.0 °C under the brooder, the calculated heat loss by radiation was 0.74W for the birds fed the diet supplemented with oil, while those fed the control diet presented 2.54W radiant heat loss. This indicates that the infrared thermal camera was effective in identifying the reduction in metabolic heat production of birds fed diets with higher energy content by oil supplementation.

Radiation is a form of heat loss through infrared rays that involves the transfer of heat from one object to another without any physical contact, and it is important in determining the emissivity of the actual skin temperature (Ring, 1995). Skin emissivity varies from 0.86 to 0.98 (Hejazi et al., 1992; Nääs et al., 2010). The body of a warm-blooded (homeothermal) animal can be divided into core, which temperature is kept within narrow ranges and independently from environmental temperature, and a peripheral area, which temperature is strongly influenced by environmental temperature (Wenger, 1996).

Metabolic heat is produced inside the body and distributed throughout the body by the bloodstream. It is transported by conduction to the surface of the body (Fiala et al., 1999) and it is lost to the environment in the form of sensible (radiation, convection and conduction) and latent (evaporation) heat when the environmental temperature is lower than the animal's body temperature. When the environment is hot, there is peripheral vasodilatation, which increases blood flow to the skin, thereby promoting the dissipation of body heat to the environment. In contrast, when the environment is cold, there is peripheral vasoconstriction to limit the amount of heat brought by the blood to the skin surface, reducing which reduces heat loss to the environment (Gray, 1997).

Calculating heat loss by radiation in kcal, birds in T1 presented a heat loss equivalent to 0.64kcal h[-1], whereas those in T2 had 2.18kcal h[-1] heat loss. This indicates that the increase in dietary oil content may reduce metabolic heat production in broilers, and therefore may be an interesting alternative to alleviate heat stress during periods of high environmental

temperature. Environmental temperature and relative humidity (RH) directly influence sensible and latent heat loss (Brossi, 2009).

Environmental temperature is considered the most important physical factor affecting the performance of broiler chickens since it exerts significant influence on feed intake (Teeter et al., 1984), thereby directly affecting weight gain and feed conversion. Reductions in feed or metabolic substrate intake decrease fuel available for metabolism, thereby reducing heat production. Thus, a diet formulated for thermal neutral conditions would not be adequate to supply the energy requirements of birds reared in heat stress environments (Oliveira et al., 2000).

The direct visual determination was only possible with the use of infrared thermography, which is the recommended method for direct assessment. It allows obtaining the temperature of a surface by quantitatively measuring thermal radiation emitted from certain surface, and it also accurately detects small variations in skin temperature (Maldague, 2001). Another advantage of using infrared thermographic images, as compared to other temperature measurement methods, is that it allows the simultaneous acquisition of a large number of photo elements (pixels) in a very short time and real-time image processing (van den Heuvel et al., 2003).

Heat loss in poultry was evaluated by Yahav et al. (2004), who found significant physiological changes when the thermal and metabolic balances were affected. A more precise estimation of heat production during broiler rearing, from hatching to slaughter, may allow the formulation of diets that meet more precisely broiler requirements, stimulating their intake during periods of high environmental temperature, and studies such as the present one may contribute to this type of feed formulation.

CONCLUSIONS

Infrared thermography analysis effectively identified the metabolic activity of broilers fed diets with different energy levels and reared under low environmental temperatures by recording their surface temperature.

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