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REGULAR ARTICLE

Broiler production efficiency: An analysis using thermal infrared images

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Abstract

The study objective was to evaluate the efficiency of using technology focusing on the thermal comfort of broilers in two poultry houses located in the metropolitan region of Teresina, Northeast Brazil, with different technological levels. One level uses cooling control of the housing and adopts high management of good production practices (Tech 1), while the second (Tech 2) was considered to use deficient technology during production. We analyzed the birds' surface temperature and the environment using infrared surface temperature data. Data were collected at a mean distance of 1 m from the birds using an infrared camera to construct the thermograms on the targets (broilers and surroundings). Data were processed using thermograms, and Boxplot graphs were built. It was found that broilers housed on the farm with higher environmental control (Tech1) obtained a better feed conversion and had more significant weight gain and greater profitability. This indicates that the greater the investment to mitigate heat stress, the better the producer's economic performance in this activity.

Keywords

Thermal Image; Surface Temperature; Performance; Poultry Production

Introduction

In tropical countries like Brazil, maintaining animal production efficiency is a challenge, mainly due to high temperatures in certain regions, leading broiler producers to face controlling heat stress, especially in the hottest periods of the year. Broilers are homeotherm animals, and 80 % of the energy ingested is used to maintain body temperature, and only 20 % is used for production. The body core temperature of birds is 41.7 °C; however, this mechanism is effective only when the ambient temperature is within certain limits, and the houses must have ambient temperatures close to the comfort conditions for the birds to maintain their optimal metabolic functions (Abreu & De Abreu, 2011; Barbosa et al., 2017). Adopting environmental cooling technology in the activity is essential for productivity gains. However, intensive management usually means that the animals have reduced area for necessary behavioral adjustments (Dalólio et al., 2016). The authors also point out that the integration of the poultry sector also contributed to fostering productive processes with greater technological diffusion. The productivity indexes depend directly on the rearing thermal environment conditions, emphasizing the thermoneutral zone of broilers (Dalólio et al., 2016), sustaining environmental thermal comfort, as maintaining a balanced body temperature is essential to promote good performance (Barbosa et al., 2017). Broilers farmers use available technologies to make the production system more efficient (Paulino et al., 2019). Forced ventilation and other technological innovations have also been used to mitigate heat stress. As it is one of the most modern animal husbandry segments, broiler production grows steadily and searches for improvements in the broilers' facilities.

Infrared thermography is a non-destructive testing technology that can determine the surface temperature of objects. According to Tessier et al. (2003), thermal images are an imaging technique that can estimate the average temperature of an area of the skin by measuring the emission of infrared energy within a predetermined spectral range. The same author mentions that the technique has been widely used in several fields of human medicine (Black et al., 1990; Armstrong et al., 1997; Bouzida et al., 2009), in horses (Tessier et al., 2003; Graf von Schweinitz, 1999), and other species (Zinn et al., 1985; Gabor et al., 1998. One of the first studies using thermography in birds was carried out on chickens with bare necks submitted to different ambient temperatures. In poultry breeding, thermal imaging has also been used to obtain the surface temperature of broilers by correlating their body temperature (Xiong et al., 2019). The knowledge about broiler chickens' surface temperature (ST) collaborates to assess their thermal comfort since temperatures change during the growing period. Therefore, thermal infrared cameras are valuable tools to measure this surface

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temperature. Broilers can be used to assess their average temperature (Nascimento et al., 2011). The technique has great importance in the calculation of heat and mass transfers between birds and the environment around them for the dimensioning of evaporative ventilation and cooling systems, such as inference on bird management (Yahav et al., 2004; Curi et al., 2017)

The objective of the present study was to assess the thermal comfort impact on broiler production efficiency. We evaluated the use of cooling technologies in two poultry houses located in the metropolitan region of Teresina, State of Piauí, northeastern Brazil, with different technological levels, correlating the surface temperatures of the birds and the environment using data of infrared surface temperature. The research question was to identify whether infrared thermal images would provide enough evidence for evaluating broiler housing efficiency.

Materials and methods

Broiler farms and flocks

The research was carried out on two farms located in the metropolitan region of Teresina, State of Piauí. The farms belong to a poultry cooperative (5.048142 S; 42.765361 W), whose function within the local poultry production chain is to supply inputs (day-old chicks and feed) to the cooperative members and sell the slaughter-age birds. The cooperative is also a link between the suppliers of inputs and services for its members, responsible for producing, storing, distributing, and commercializing feed.

The cooperative has created a classification for farms ranging from good, with scores between 5,603 to 3,081, as shown in Table 1.

Table 1. Classes of broiler farms, technological level, and range of scores.

Class	Technological level	Range of scores
A	Good	5,603 to 5,043
B	Satisfactory	5,042 to 4,482
C	Regular	4,481 to 3,922
D	Low	3,921 to 3,082
E	Very low	< 3,081

The studied houses belong to cooperative members, attributing a score to each affiliated member. The score consists of a scale related to the farmers' technological level, and it is a scale from "A to E," being "A" the highest score and "E" the lowest.

The first selected farm is located in the municipality of Altos, called Tech1 (5.02392 S; 42.33539 W), classified as "A" by the technological level, and the other is in Teresina (5.64631 S; 42.431636 W), called Tech2, classified as "B." Both climatic characteristics, according to Koeppen, are Aw, a tropical climate of savana. Both adopt the intensive farming system, using a mixture of wood shavings and rice straw 8 cm thick for litter. With the Tech1 farm building's production area with a 21,450 heads per cycle housing capacity, the Tech2 building has a housing capacity of 12,441 heads per flock, with construction details shown in Table 2.

Table 2. Construction data and equipment detail used in the broiler houses.

Broiler house	Fan (number)	Fogging	Automatic feeder	Bell drinker	Height (m)	Tile type and k ($Wm^{-2}K$)	Floor area (m^2)	Roof lining
Tech1	21	30	600	400	2.8	With isolation (k=0.022)	1652	Y
Tech2	8	1	72	202	3.5	Ceramic (k=0.05)	957	N

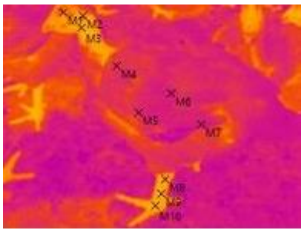
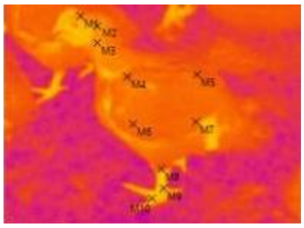
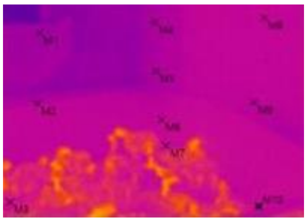
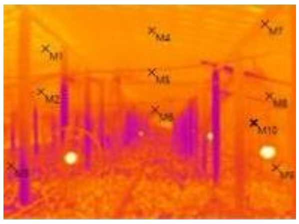
Fan = 1-HP axial fan; Fogging = number of fogging sprayers; and Roof lining = lining using polypropylene sheet.

Thermal images and surface temperature recording

Two poultry houses with positive pressure ventilation systems were used. The two houses were divided longitudinally into three parts and perpendicularly into two parts for data collection, totaling six quadrants. Three sets of data and images were recorded in each quadrant, one reading on the right, one in the center, and one on the left. Thermal images were captured at 2 PM using a Testo® infrared thermal camera (Testo 882, Testo Instruments, Lenzkirch, Germany) with a high resolution (320 x 240 pixels) precision of ± 0.1 ºC and a spectrum range of 7.5 - 13 µm.

Birds were between the fifth and sixth week old in each house. The camera was set at approximately 1m from the birds, and at the same point, it was zoomed out to record the environment and the surroundings. Ten records were made to analyze the temperature of the microenvironments and birds. Data were registered in two commercial farms located in the metropolitan region of Teresina, in the State of Piauí, in a batch of broiler production. The houses were divided into three equal parts in length. The surface temperature of the birds, walls, and litter was recorded, characterizing three microenvironments. Based on these images, the birds' mean surface temperature (MSTB) was calculated by selecting 10 points in the image area (Table 3, Tech1 c, and Tech 2 d) to calculate the average temperature (Nascimento et al., 2011). Panoramic thermal images were recorded to evaluate the houses' rearing thermal conditions (Table 3, Tech1 e, and Tech2 f). The surface temperatures were calculated from 10 selected thermal images *per* house *per* day of recording. The actual images inside the houses are shown in Table 3 Tech1 a and Tech2 b).

Table 3. Information on the housing characteristics of the two studied houses.

Description	**Tech1**	**Tech2**
The actual picture inside of each broiler house	 a	 b
Thermal image of the reared broiler in each house	 c	 d
The thermal image inside of each broiler house	 e	 f

Surface temperature assessment

For the surface temperature recording, first, we recorded the thermal images of the flock aiming at a group of birds (Nääs et al., 2010). The thermal images of the rearing area were recorded as suggested by Baracho et al. (2011). The surface temperature recording took place on consequent days at 2 PM, and the farms are in the same geographic area (Tech 1 at 5°02'39" N; 42°33'53" E and Tech 2 at 5°64'63"N; 42°43'16" E). A blue/red color scheme was used for analyzing all images, and the chosen temperature scale was between 30 ºC and 45 ºC. The thermal camera was placed at approximately 1 m. The image was recorded using an angle of 90º from the surface to minimize the error, which is negligible for objects with a rough surface, such as broilers (Table 3, Tech1 c, and Tech2 d). The emissivity coefficient (ε) used was 0.94 (Nääs et al., 2010), within the range of emissivity values for biological material. There are several suggestions for this matter in the literature (Malheiros et al., 2000; Cangar et al., 2008).

Mean surface temperature (MST) and standard deviation (SD) of the studied surface areas were calculated using the temperature measured at several randomly chosen points located within the chosen body parts (Table 3, Tech1 c, and Tech2 d). To build the thermograms, ten points were selected for each target (broiler and surroundings). Each thermogram was processed and analyzed using software provided by the camera manufacturing company (IRsoft®, Testo Instruments, Lenzkirch, Germany).

Results and discussion

Housing temperature inside A differed from B, being higher in the house using less technology Tech2 ($p < 0.001$) (Table 4). Broiler surface temperature did not differ between both studied houses ($p=0.505$).

Table 4. Results of the surroundings and broiler surface temperature inside the houses.

Broiler house	Inside temperature (°C)	SD	Broiler temperature (°C)	SD
Tech 1	32.8[a]	2.5	32.8	2.5
Tech 2	36.7[b]	2.0	32.4	1.6

SD=standard deviation. The letter in the column indicates a significant difference $p<0.05$).

Figures 1a and 1b show the surface temperature distribution of the surroundings and reared broilers inside the house with a higher technology level.

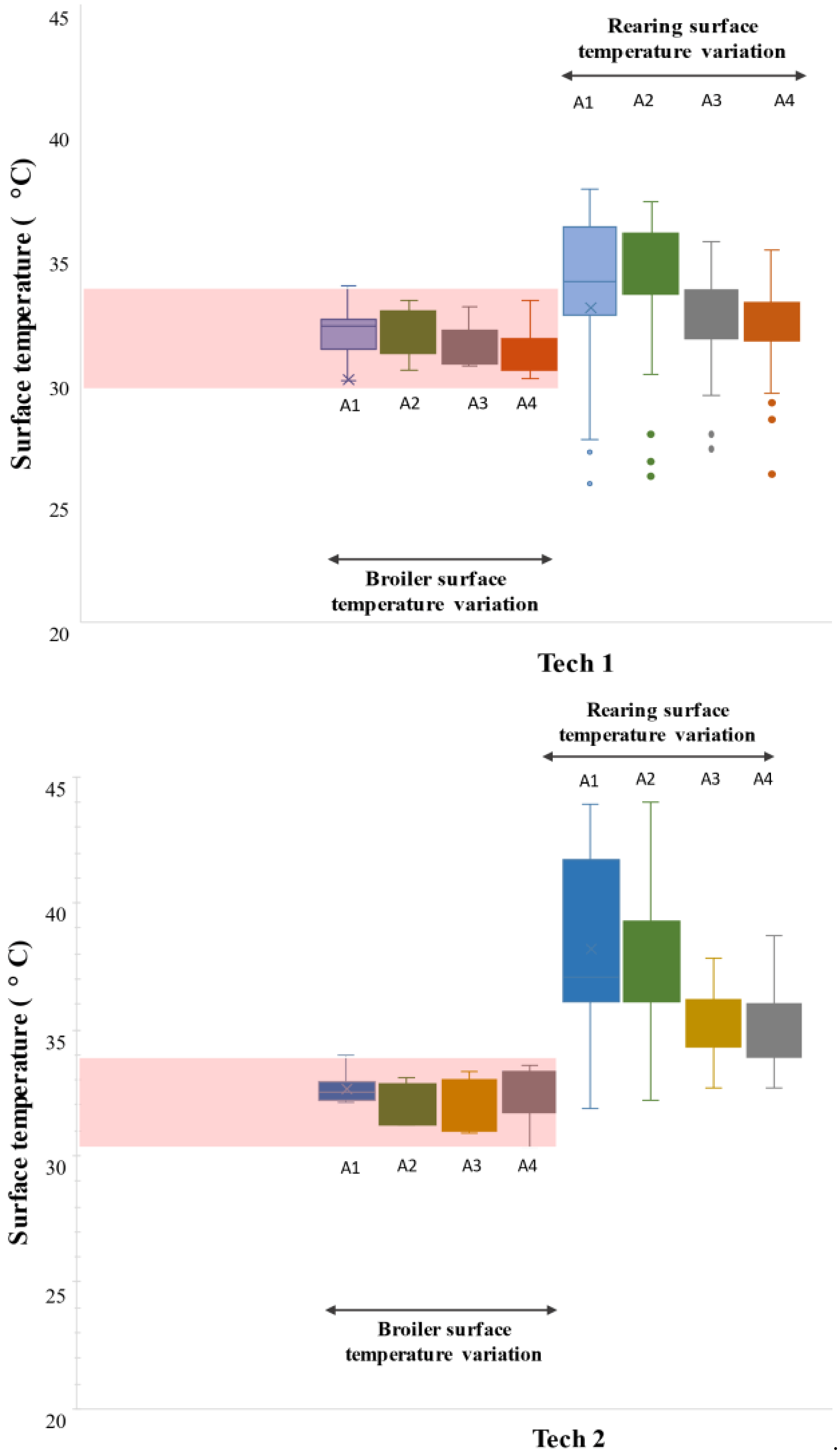


Figure 1. Distribution of the broiler and environment surface temperature inside two different housing types with a distinct technology levels (a and b). The thermal comfort zone is within 30 and 34°C with fans on.

The flock performance was assessed after the broilers were slaughtered, encompassing the average daily weight gain (AWG), feed conversion (FC), and productivity index (PI). Feed ration and management adopted were those suggested by the breeder's company, and we did not interfere in the general flock management. Table 5 presents the performance data on the two flocks reared on both tested management technologies.

Table 5. Data related to the studied broiler houses and the performance and productivity indexes.

Broiler house	DWG	FC	PI	Score
Tech 1	62.715	1.718	345.37	A
Tech 2	59.076	1.730	327.76	B

It was evident that, although the temperatures of broilers at Tech 2 are similar to those at Tech 1, the higher incidence of higher temperatures at Tech 2 leads to the worse historical performance of flocks at Tech 2. The studied area has a tropical climate with high temperatures and air humidity for most of the year because it is located between the tropics of Cancer and Capricorn (Köppen & Geiger, 1928), cited in Cordeiro et al. (2010), becoming one of the main limiting factors for the creation of broilers in climatic conditions. The association of these climatic parameters favors the discomfort of bringing the most unpleasant thermal sensation to the animals. Thus, the environmental conditions in which the birds are housed are among the main concerns of current Brazilian poultry farming. (Silva & Vieira, 2010).

For this reason, there is a need to adopt technologies to cool off the house environment. Figure 2 shows the schematic results, indicating that the adoption of cooling technologies impacts performance and well-being.

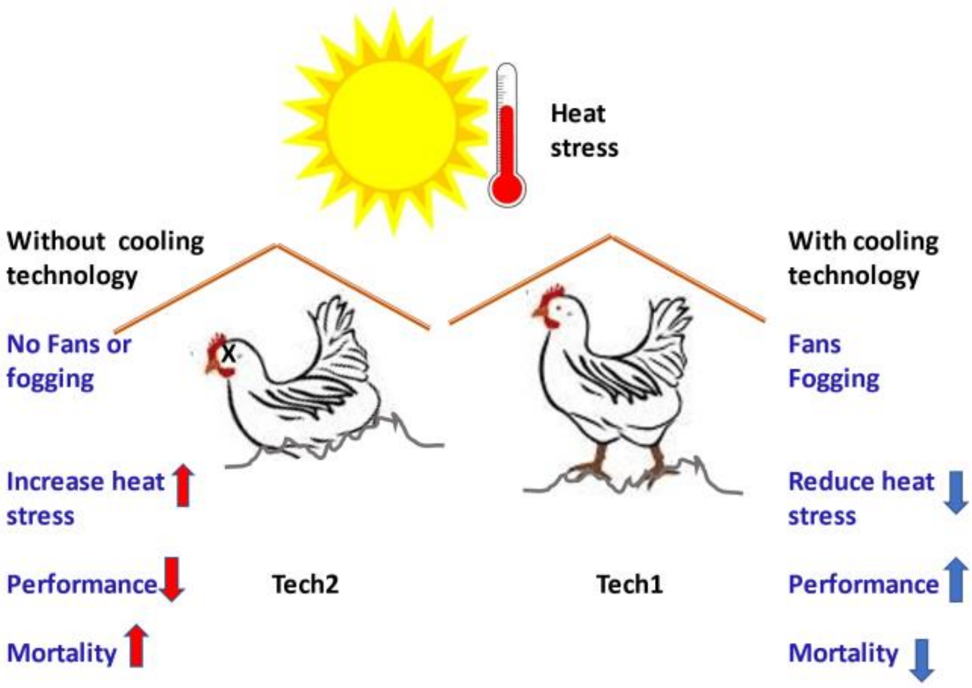


Figure 2. Schematic view of the comparison between the two broiler houses using two different technology levels.

Broiler production has increased significantly in the region in the last few years. According to the climatic characteristics and low technology, broilers are raised using a flock density near 14 birds m^{-2}. The production costs have an average cost per head of US$ 2.11 compared to US$ 2.00 in the southern region of Brazil (Franco et al., 2019).

Broiler productivity is directly related to the rearing environment (Giloh et al., 2012). In these studied houses, mitigation of a hot environment is provided by the proper use of fans and fogging systems that give evaporative cooling benefits (Liang et al., 2020), found in houses with higher technology. Heat stress is harmful to poultry production, with undesirable effects on productivity, bird welfare, and mortality leading to economic losses. Several studies have shown that air velocity can significantly impact broiler performance, including weight gain (Gillespie et al., 2017; Liang et al., 2020; Kang et al., 2020; Kyung-Woo et al., 2020, Kyung-Woo et al., 2021). Forced ventilation allows greater control over air velocity, leading to more significant body weight gain. (Kang et al., 2020).

When exposed to rearing temperatures above the upper critical zone (> 35 °C), broiler chickens cannot dissipate the body's heat, and physiological illnesses appear following multi-organ dysfunction that might result in death. The mortality rate was below 3% per flock in the studied environment, acceptable as usual (EMBRAPA, 2016). Previous studies indicate that diet and feed strategies mitigate heat stress (Shakeri et al., 2020); however, changing diet and feed strategy sometimes is not possible on-farm. Modifying the rearing environment using cooling strategies is more definitive and provides a better solution for hot climates (Liang et al., 2020).

According to Iyasere et al. (2021), broilers are more tolerant to moderate heat stress (30°C, 70% RH) than to high heat stress (32°C, 70% RH), the latter of which results in some mortality. However, moderate heat stress for six hs or high heat stress for three hs had a similar impact on both welfare broilers, in terms of several welfare indicators, including change in core body temperature and selected blood parameters, as well as the performance of broilers, based on estimates of feed consumption and weight gain.

It is well documented in current literature that economic losses in the poultry sector due to thermal stress are significant worldwide (Liang et al., 2020; Kyung-Woo et al., 2021). In tropical countries, where the average ambient temperature rises above 30 °C during the summer, poultry is seriously affected due to increased mortality during heat stress. The bird's body temperature increases, leading to emergency physiological responses (Plantharayil et al., 2019). Birds are vulnerable to high-temperature environments. Their feather-covered body and absent sweat glands reduce heat exchange efficiency between the body and the environment, typically seen in mammals. Therefore, increasing their respiration rate is one of the main ways birds maintain their body temperature under rising ambient temperatures. One of the most damaging effects of thermal stress is mortality, which is easy to assess on the spot on farms when birds are exposed to severe thermal environments. However, since there is no standardized method for recording mortality or accurate records of age or causes, it is difficult to summarize the available data on chronic heat stress mortality (Kang et al., 2020).

The projections on the future market the annual global meat consumption *per capita* is expected to reach 35.3 kg in 2025, an increase of 1.3 kg compared to the last five years. This additional consumption will mainly consist of poultry meat and almost 90% broiler meat. In absolute terms, growth in total consumption in developed countries during the projection period is expected to remain small compared to developing regions, where accelerated population growth and urbanization remain the main drivers (OECD/FAO, 2018). According to this projection, the growth in per capita consumption, compared to the base period (average from 2015 to 2017), will increase by 2.8 kg in developed countries and half in developing countries. Over the next decade, broiler meat production will benefit from better feed conversion ratios and, in part, from positive price margins between meat and feed and better feed conversion rates. Increased productivity will also lead to a positive supply response and lower meat prices for the projection period.

Consumption of animal products tends to increase in developing countries. Livestock will have to increase production to meet demand, opening the door to increased automation and technological innovation intensely and sustainably. The use of technologies that help mitigate heat stress is needed, and technologies that provide accurate data can improve a well-managed farm. Developing methods to turn data into actionable solutions is critical (Halachmi et al., 2019).

Conclusions

It was found that the broilers housed in the Tech 1 farm, adopting a greater control of the environment, had a better feed conversion, generating a higher weight gain and obtaining greater profitability than that adopted by Tech 2. The thermal infrared images helped assess technology adoption efficiency, and such technology implementation leads to better animal housing and improved economic performance.

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