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Thermal environment of masonry-walled poultry house in the initial life stage of broilers

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ABSTRACT: The aim of this study was to monitor and evaluate the thermal environment and undertake a complete mapping of the variables air temperature, air relative humidity, and temperature-humidity index for broilers. The research was conducted during the winter, in Brazil, in a commercial poultry house fully walled with concrete-block masonry, equipped with a full-time negative-pressure mechanized ventilation system and indoor-environment air heating by a wood-burning furnace located outside the facility. The shed was fully automated and housed 30,000 birds at a density of 15 birds m^{-2}. Thermal-environment data analysis revealed that the masonry-wall model did not ensure homogeneous thermal distribution within the poultry house, with the central region showing the highest air temperature and lowest air relative humidity values. The indoor environment did not provide thermal comfort to the housed birds, which were under thermal discomfort in certain situations in some internal regions of the shed.

Key words: industrial poultry farming, poultry facilities, animal environment

Ambiente térmico de aviário com fechamento em alvenaria na fase inicial para frangos de corte

RESUMO: Objetivou-se com esta pesquisa monitorar e avaliar o ambiente térmico e realizar o mapeamento térmico completo das variáveis temperatura do ar, umidade relativa do ar e índice de temperatura e umidade de aviário para frangos de corte. A pesquisa foi conduzida durante inverno, no Brasil, em aviário comercial, com fechamento completo em alvenaria de blocos de concreto, sistema de ventilação mecanizada por pressão negativa em período integral, e aquecimento do ar do ambiente interno via ar aquecido por fornalha a lenha localizada externamente à instalação. O aviário é totalmente automatizado, possuindo 30.000 aves alojadas na densidade de 15 aves m^{-2}. Diante da análise dos dados do ambiente térmico verificou-se que o modelo de instalação com fechamento em alvenaria não garantiu distribuição térmica homogênea no interior do aviário, com a região central apresentando os maiores valores de temperatura do ar e os menores valores de umidade relativa do ar. O ambiente interno não permitiu conforto térmico às aves alojadas, as quais se encontraram para determinadas situações, em algumas regiões internas ao aviário, sob desconforto térmico.

Palavras-chave: avicultura industrial, instalações avícolas, ambiência animal

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Introduction

Poultry farming is one of the most important activities of the Brazilian agricultural sector. Great advances and investments have been continuously put forward in the area, leading Brazil to rank second and first as producer and exporter of chicken meat worldwide, respectively (ABPA, 2018).

However, the predominant tropical and subtropical-climate characteristics of Brazil require a great deal of specific care. In this regard, specific architectonic and constructive typologies as well as differentiated environmental management systems predominate, but these often vary as a function of the production costs of each element involved in the activity. This causes the rearing system to be an ongoing challenge for the poultry production systems adopted in the country (Abreu & Abreu, 2011).

The greatest challenge, however, is that due to mainly economic questions regarding their initial cost of construction, Brazilian poultry houses have failed in terms of thermal insulation, which is rather weak in practically all sheds. As a consequence, birds are often stressed by either cold or heat, despite the generally low thermal amplitude (Hernandez et al., 2016b).

Although most part of overheating originates from the roof (Machado et al., 2012), a new typology for poultry houses has emerged in Brazil wherein movable curtains on all walls are replaced with concrete-block or ceramic-brick masonry walls. Thus denominated "solid poultry houses", these facilities encompass the ease of management of the environment-conditioning system and improved thermal conditions (Costa et al., 2010).

On these bases, the present study was conducted to undertake a complete thermal mapping of a masonry-walled broiler house as well as to identify the thermal variability and analyze the environmental variables such as air temperature, air relative humidity, and temperature-humidity index during the initial life stage of birds.

Material and Methods

The trial was conducted during the winter of 2015, in June and July, on a commercial broiler farm in the state of Minas Gerais, Brazil. The municipality is called Piranga, located at latitude 20° 39' S and longitude 43° 17' W, 720 m above sea level. The facility used in the research (dimensions: 145 m length × 14 m width × 3.0 m ceiling height) had polyurethane lining at 2.6 m above the floor, a metal structure, and corrugated galvanized-steel tiles.

The poultry house was entirely closed on the sides with 0.2 m thick concrete blocks lined on the inside with cement + sand mortar later painted white. The house was equipped with a negative-pressure forced-ventilation system with nine exhaust fans and evaporative adiabatic cooling of the inlet air via a pad-cooling system.

An additional misting system was also present in the facility, in two mist lines positioned along the facility's length axis. The heating system consisted of a wood furnace located outside the poultry house, where the generated heat (via heated air) was led to the center of the house through galvanized-sheet pipes.

A negative-pressure system was adopted at all times for thermal conditioning, consisting of two groups of exhaust fans activated gradually by automated control panels. A total of 30,000 male birds were housed at a density of 15 birds m^{-2}.

The 1-Wire™ system was implemented in the experiment to collect air temperature data (temperature sensors DS2438, accuracy of 0.5 °C in the temperature range of -10 to 85 °C), whereas a HOBO® data logger model U14-002 was used to collect air relative humidity data.

Forty air-temperature sensors were distributed uniformly and equidistantly inside the house at a height of 0.2 m from the mid-height of the back of the birds. Eight air relative humidity sensors were also distributed similarly to the temperature sensors (Figure 1).

A weather station, located 15 m distance from the barn, at 1.5 m height, with air temperature DS2438 sensors and relative humidity U14-002 sensors, protected from direct solar radiation, was used to evaluate air temperature and relative humidity in the environment outside the poultry house.

Temperature and humidity data were collected continuously (24 h d^{-1}) during the entire initial life stage of the birds from their arrival as chicks until the end of the heating period, totaling 18 experimental days. Monitored data were recorded in real time, at 1 min intervals.

The thermal environment evaluation was presented in maps for the day and nighttime periods for every week of life of the housed birds and also in graphs representing the entire experimental period. The software Sigmaplot 11.0® was used to plot maps of air temperature, relative humidity and temperature-humidity index (THI) from inside the facility. The temperature-humidity index (THI) was determined based on the collected air temperature and relative humidity data, following Thom (1959).

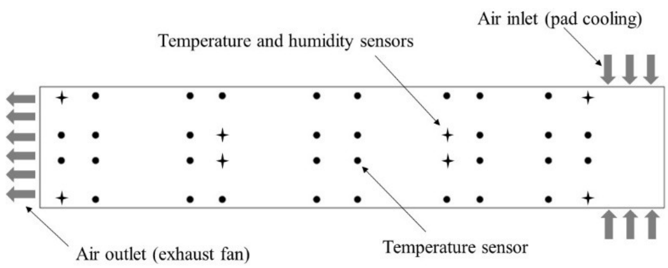

Figure 1. Layout of the ventilation system and arrangement of air temperature/relative humidity sensors inside the poultry house

Results and Discussion

Figure 2 contains the maps of mean air temperature recorded in the day and nighttime periods inside the shed during the first, second, and third week of life of the birds.

A similar behavior was observed for distribution of mean temperature in the first and second week, as shown in the maps in Figures 2A and B, wherein the central region of the facility showed the highest values, as the heating system was located at that point.

The air temperature decreases as one draws further from the center of the shed; accordingly, the lowest temperatures

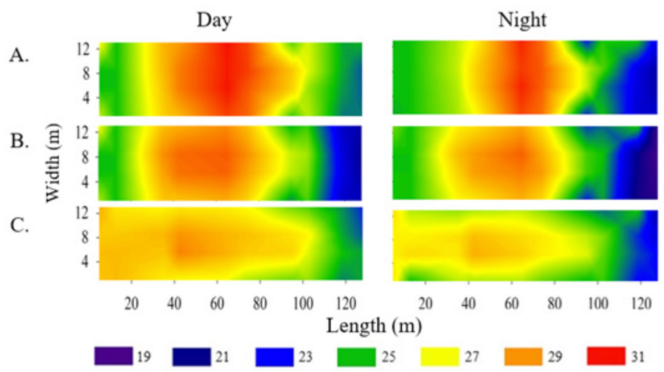

Figure 2. Maps of air temperature (°C) distribution across the poultry house in the day- and nighttime periods. Mean temperature in the first week (A), mean temperature in the second week (B) and mean temperature in the third week (C)

are found at the extremity of the house, where the air inlet is located. In the initial life stage of the birds, the space designated for animal occupation was the central region of the shed, and thus no birds were present near the air inlets.

In the three weeks, greater thermal variation was observed in the nighttime period (approximately 10.7 °C), and the highest variation was observed in the second week. The greatest thermal variation during daytime was observed also in the second week (around 8.8 °C).

This greater variation at night may be attributed to the wider thermal amplitude occurring in nighttime periods, with marked temperature drops at dawn. Besides, the mean nighttime outdoor temperature being lower than that inside the poultry house may contribute to lowering the indoor temperature, especially in the region near the air inlet.

As described in the literature, the ideal temperature for broilers in their first week of life is 32 to 34 °C; in the second week, between 28 and 32 °C; and in the third week, from 26 to 28 °C (Tinôco, 2001; Medeiros et al., 2005; Oliveira et al., 2006; Pauli et al., 2008; Ferreira, 2011). The temperature values recommended by the manual of the strain of the broilers housed in the facility addressed here, however, are 34, 31, and 27 °C for the first, second, and third week, respectively (COBB-VANTRESS INC., 2012).

The mean temperature in the first week of life ranged from 21.4 to 30.9 °C, which is below the values recommended in the literature and much lower than those suggested in the manual of the strain, indicating that the birds were under cold stress during that age range.

In the second week, the mean temperature ranged between 19.1 and 29.8 °C, and only the central region of the shed reached the range recommended in the literature, despite remaining below the 31 °C suggested by the manual of the strain. Therefore, the birds housed in the other regions were under stress.

Cold stress in the initial stage was also observed by Vigoderis et al. (2010), Menegali et al. (2013), and Paula et al. (2014), who evaluated the thermal environment of poultry houses during the heating stage in the winter period. As described by those authors, the air temperature did not reach the adequate conditions for the birds.

In an evaluation of the behavior of broilers in the initial life stage through images, Schiassi et al. (2015) found that under thermal stress conditions caused by the cold - a situation occurring in facilities with insufficient heating and flaws, similarly to the present study - birds tend to remain most part of the time clustered in groups, which compromises their development and productive efficiency.

Cândido et al. (2016) observed that broilers reared under the temperatures of 27, 24, and 21 °C in the first, second, and third week, respectively, which are lower than those recommended in the literature, showed higher weight gains and feed conversion in comparison with the other imposed temperatures of comfort and cold stress.

During the third week, a large part of the interior of the shed was within the suggested temperature ranges, with variations between 21.9 and 29.3 °C. As shown in the maps in Figure 2C, the center of the poultry house had air temperature values higher than the 28 °C recommended in the literature and the 27 °C recommended in the manual of the strain, suggesting that the birds in that region were under heat stress.

The concrete walls were found not to be a good thermal insulating agent to ensure the thermal inertia of the poultry house, which negatively affected its thermal uniformity along with the inadequate heat distribution of the heating system. Carvalho et al. (2011) stated that the difficulty to maintain the air temperature in the area during initial bird growth under thermal comfort conditions is usually related to inefficient thermal insulation of these areas.

According to Carvalho et al. (2012) and Saraz et al. (2012), the distribution of heated air within a facility is influenced by its type, ventilation system, insulation, air temperature and relative humidity, and mainly by the heating system employed.

Hernandez et al. (2016a) mapped a broiler house with a negative-pressure ventilation system and curtain walls and observed that, in the first three weeks of life, air temperature was within the thermal comfort zone, whereas at night temperatures were slightly lower than during daytime. The authors also detected regions with lower temperatures as being those near the air inlets, similarly to these findings.

As described by Ponciano et al. (2012), because birds do not have a defined thermoregulatory system or sufficient energy reserves to adapt to the adverse environmental conditions in the first days after birth, their body temperature may change as a function of the environment temperature.

Cassuce et al. (2013) evaluated the performance of broilers in the first three weeks of life in environmental chambers and found that birds kept in a temperature program of 30 °C in the first week, 27 °C in the second week, and 24 °C in the third week - which are below the values recommended in the literature - have better performance compared with birds under different environmental conditions.

The temperature values classified as ideal by Cassuce et al. (2013) are within the variation ranges observed in the first and second week of life of the birds housed in the masonry-walled shed.

The variations in the mean indoor and outdoor temperatures of the shed are shown in Figure 3A . Inside it, the temperatures showed a balanced trend, which was expected since the heating system was activated the entire time, although small temperature peaks occurred during daytime, with milder temperatures at night.

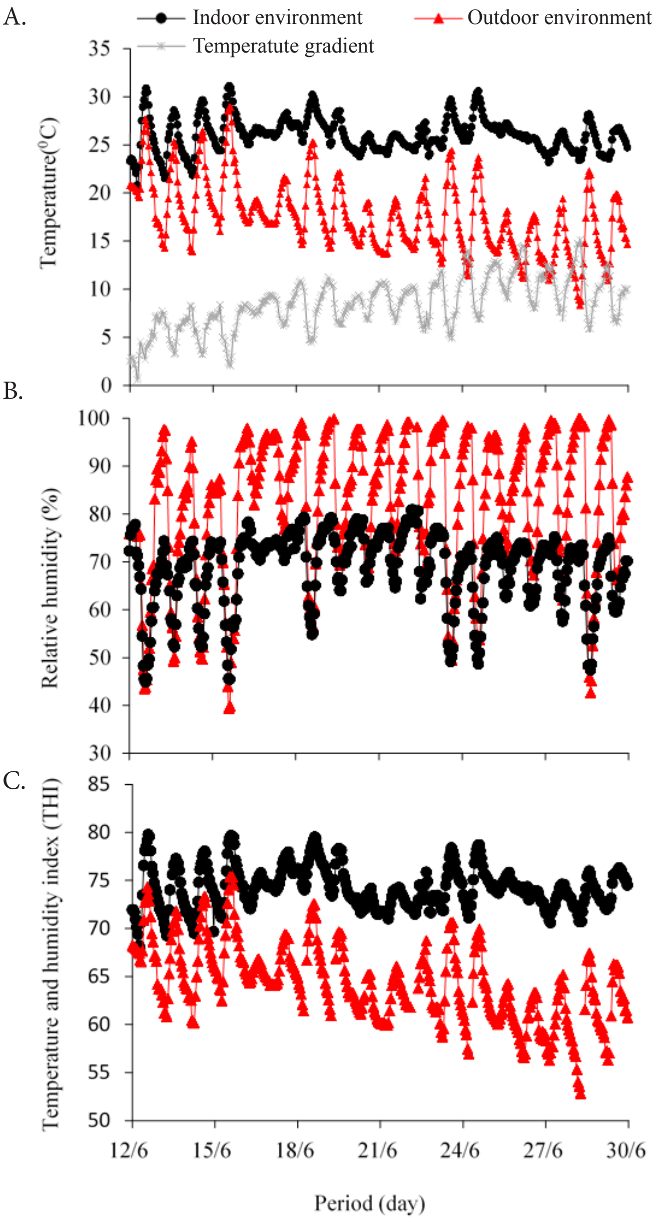

Figure 3. Mean air temperature and the difference between the mean indoor and outdoor air temperature (mean Δt) (A), mean air relative humidity (B), and mean temperature-humidity index (C) in the indoor and outdoor environments of the poultry house

Greater thermal variation was observed for the mean outdoor temperature, mainly in the start of the heating phase. There was a decline in outdoor temperature as the days went by, but the indoor shed temperatures were not influenced, as shown in Figure 3A. The mean ΔT, which is the difference between the mean indoor and outdoor air temperatures, was 8.47 ± 2.7 °C, increasing from the first to the last days of heating.

The ΔT observed in this experiment was higher than those reported by Hernandez et al. (2016a), who worked with negative- and positive-pressure, curtain-walled poultry houses and obtained mean ΔT values of 4.7 ± 2.9 °C and 4.2 ± 4.1 °C, respectively, in the initial life stage of the birds.

The higher difference between mean indoor and outdoor shed temperatures observed in this study in comparison with the values reported by Hernandez et al. (2016a) demonstrates the greater thermal insulation capacity of poultry sheds fully walled with masonry compared with curtain-walled poultry houses. However, it was not sufficient to ensure adequate thermal conditions to the birds.

As shown in Figure 3A, throughout the days, the mean temperature of the shed in the first and second week of housing was below those preset in the cooling panels for that period, which would be 34, 31, and 27 °C for the first, second, and third week of life of the birds, respectively.

This occurrence is possibly attributed to the fact that the sensors controlling the conditioning systems (heating and ventilation) are not located in positions that represent the thermal reality of the entire or most of the air volume in the shed. It can also be attributed to the fact that the heating system concentrates most part of the heat produced near the pipeline's outlet, and consequently the air temperature declines as one moves further from the heating pipeline.

As can be observed in Figures 4A, B and C, a similar distribution pattern occurred for air relative humidity inside the shed between the weeks and periods of the day. The lowest humidity was recorded in central strip across the poultry house, mainly in the geometric center of the facility.

The central region of the shed is where the heating pipeline is located, which generates higher air temperature and consequently lower air relative humidity values. The highest humidity values, however, are observed around the internal border of the shed.

Similar results were observed by Hernandez et al. (2016a), who mapped curtain-walled poultry houses where the air relative humidity near the heating system was also lower than that observed in the other regions of the facilities, with humidity levels below 40% occurring in the seven first days of bird housing.

Despite the similarity in distribution, a higher mean air relative humidity occurred during the nighttime period, with 80% humidity reached in the first week. During daytime, however, maximum humidity was 74%.

For most parts of the shed, in the three weeks, mean air relative humidity values were within the range of 50 to 70% suggested by Tinôco (2001), Furtado et al. (2003), Sarmento et al. (2005) and Dalólio et al. (2015). The highest humidity values, which also exceed this maximum limit of 70%, were found at the extremities of the shed, but the birds were concentrated in the central region of the facility during the heating phase.

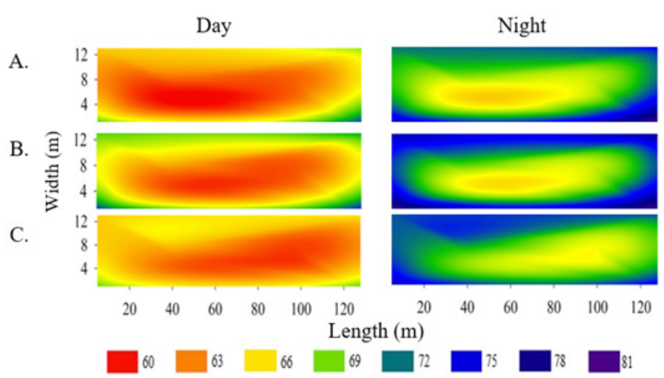

Figure 4. Maps of air relative humidity (%) distribution across the poultry house in the day- and nighttime periods. Mean air humidity in the first week (A), mean air humidity in the second week (B) and mean air humidity in the third week (C)

As illustrated in Figure 3B, constant maximum values were detected for air relative humidity in the outdoor and indoor environments, which was not the case for the minimum values. Outdoor humidity also showed a greater variation in comparison with that observed inside the poultry house, which is explained by the fact that it was a closed, semi-air-conditioned environment with greater control of the present air volume.

Throughout the heating phase, in the periods when the outdoor humidity reached its lowest levels, between 40 and 60%, the indoor air humidity behaved similarily and reached the same record levels.

In a study led by Menegali et al. (2013), the authors observed that, in the first week of life of birds, air relative humidity values during daytime were mostly below those deemed ideal. The same was reported by Cordeiro et al. (2010), who recorded air relative humidity values lower than 50% for the same period.

Air relative humidity levels below the comfort zone coupled with high air temperature values lead to dryness of the respiratory tract and possibly dehydration in birds (Carvalho et al., 2009; Cordeiro et al., 2010).

Figure 5 shows the maps of temperature-humidity index (THI) for the mean temperature conditions during the day- and nighttime periods observed inside the experimental facility in the first three weeks of life of the birds.

For all situations, a similar trend was found regarding the distribution of THI across the poultry house. A considerable rise was observed in the THI values from the extremity of the shed, where the air inlet panels were located (pad cooling of the evaporative adiabatic cooling system) towards the opposite end, where the exhaust fans were located; i.e., air outlet.

This THI distribution trend was expected, given the contribution to heat increment from solar radiation via non-insulated roofing as well as the generation and dissipation of heat by the birds themselves, which contributes to increasing the air temperature and consequently THI values, corroborating Hernandez et al. (2016a).

As was found for air temperature, the largest variation in THI was detected in the nighttime period, in the second week of the experiment. Silva et al. (2004) proposed for broilers, based on THI, thermal comfort zones of 72.8 to 80 in the first week, 68.4 to 76 in the second week, and 64.8 to 72 in the third week of life.

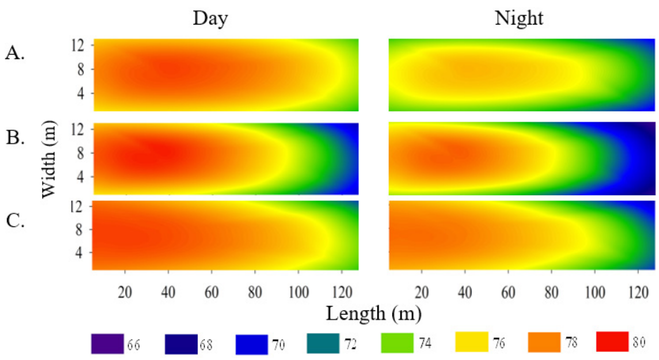

Figure 5. Maps of temperature-humidity index (THI) distribution across the poultry house in the day- and nighttime periods. Mean THI in the first week (A), mean THI in the second week (B) and mean THI in the third week (C)

The indoor THI of the masonry-walled shed ranged from 70.2 to 79.1 in the first week of life of the birds, 70.2 to 79.1 in the second week, and 68.7 and 78.8 in the third week.

Based on the values suggested by Silva et al. (2004), in the first and second week, THI reached values below the limit for those age ranges. However, as depicted in the maps in Figure 5A, the areas where these low THI values occur are regions near the air inlet, where no birds were present during the initial stage.

Temperature-humidity values above the suggested limits of 76 and 72 were observed in the second and third week, respectively, in a region of the poultry house where birds were present, as can be seen in Figures 5B and C. Thus, the animals were under thermal discomfort.

A situation of thermal discomfort was also observed by Vigoderis et al. (2014). Hernandez et al. (2016a), on the other hand, observed THI values during the first two weeks of life of birds within their thermal comfort zone, but this comfort was only found in the region near the heating system.

Figure 3C represents the mean THI recorded inside the shed throughout the heating phase as well as the outdoor THI. A similar behavior was seen throughout the days, between the indices, but with different amplitudes. The indoor environment had the highest values, as expected, because of its higher temperature. A higher variation was detected in the outdoor environment, which ranged from 53 to 75, averaging 64.2.

Conclusions

1. The facility presented thermal variability, with the highest values of air temperature and the lowest values of relative humidity of the air in the central region of the installation.

2. The facility did not provide comfort conditions to the housed birds, which were in a situation of thermal discomfort in certain periods and in some indoor areas of the shed.

Acknowledgments

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