BIOCLIMATIC LIVESTOCK ZONING OF MARANHÃO STATE, BRAZIL[1]

[MAPEO BIOCLIMÁTICO DE LA GANADERÍA DEL ESTADO DE MARANHÃO, BRASIL]

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SUMMARY

The production environment in which animals are kept can be classified by bioclimatic indexes expressing the conditions of thermal comfort to different species. In the state of Maranhão (MA), located in Northeast Brazil region, stand out in the livestock sector the beef cattle, pig and poultry production. In order to check the conditions of thermal comfort in the state for these species was held a bioclimatic zoning, taking into account the temperature and humidity index (THI) and Black Globe Temperature and Humidity Index (BGTHI). Estimates of the indexes were performed from meteorological data obtained from the database of the National Institute of Meteorology (INMET). Seven county were considered, and were chosen taking into account the greater amount of information available over the years. The variables analyzed were: air temperature, relative humidity and atmospheric pressure. Bioclimatic indexes were determined by using mathematical equations applied in Microsoft Excel®. Using the Surfer 8.0® program, were generated maps with bioclimatic zones to the state. Taking into consideration the comfort levels recommended as safe for poultry, pigs and cattle in all stages of production (THI 70-74 and BGTHI 72-75), the analyzed bioclimatic zones showed no conditions for comfort and optimal performance of these species, considering that the THI ranged from 74.1 to 75.8. and BGTHI from 80.0 to 82.3. Can be concluded that in the cities checked, the production systems of these species need investment in measures to promote the correction of microclimate to establish optimal levels of animals thermal comfort.

Keywords: animal production; bioclimatology; tropical climate; Brazil

RESUMEN

El entorno en el que los animales son mantenidos se puede clasificar por los índices bioclimáticos que expresan las condiciones de confort térmico para las diferentes especies. El estado de Maranhão (MA), situada en el noreste de Brasil, se destaca la producción de ganado vacuno de carne, la cría de cerdos y aves de corral. Con el fin de verificar las condiciones de confort térmico para estas especies, se realizó una zonificación bioclimática, teniendo en cuenta el índice de temperatura y humedad (THI) y el índice de temperatura y humedad del globo negro (BGTHI). Las estimaciones de los índices se tomaron a partir de datos meteorológicos obtenidos a partir de la base de datos del Instituto Nacional de Meteorología (INMET). Se eligieron siete condados Maranhenses teniendo en cuenta la mayor cantidad de información disponible en los últimos años. Las variables analizadas fueron: temperatura del aire, humedad relativa y presión atmosférica. Utilizando el programa Surfer 8.0®, se generaron mapas con las zonas bioclimáticas para el estado. Teniendo en cuenta los niveles de confort recomendados como seguros para las aves de corral, cerdo y ternera en todas las etapas de producción (UIT 70-74 y 72-75 BGT), las zonas bioclimáticas analizadas no mostraron las condiciones de confort y rendimiento óptimo para estos especies, ya que THI osciló entre 74.1 y 75.8 y la BGTHI entre 80.0-82.3. Se puede concluir que en las ciudades evaluadas, los sistemas de producción de estas especies necesitan inversión en medidas para promover la corrección de microclima para establecer niveles óptimos de confort térmico.

Palabras clave: producción animal; bioclimatologia; clima tropical; Brasil.

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INTRODUCTION

The State of Maranhão has an area of 331,983.29 km^2, being the eighth largest Brazilian State and the second in the Northeast in territorial extension IBGE (2002). It is located between the parallels 1° 01'and 10° 21' South and the meridians 41° 48' and 48° 50' West. Since it is in a transition zone of the semi-arid climates of the Northeast interior to the equatorial humid of the Amazon, and because has greater extent in the north-south direction, present differences in climate and rainfall. In the West region, predominate the hot and humid tropical climate (As), typical of the Amazon region. In other regions, the State is marked by hot and semi-humid tropical climate (Aw). According to Köppen and Geiger (1928) classification, in Maranhão the climate is Aw type, with average temperatures always higher than 18°C, and two well-defined climatological stations, a dry season from June to October and a rainy season, from January to April.

The livestock production of the state stands out for beef cattle being the main economic activity of the livestock sector with about 7,611,324, designed almost entirely to the court. The pig production recorded a roster of 1,320 953 000 heads, representing 3.4% of the national production, followed by poultry production of about 0.7% of the national total PPM (2013).

The weather is a major factor affecting animal production, and it knowledge is strategic for the design of installations and cooling systems and the handling of animals. Thus, to allow the animals to express all their productive potential, it is necessary to consider the interaction between genetics, nutrition, health and thermal environment Baêta and Souza (1997).

The environment in which the animals are raised can be classified by bioclimatic indexes, which are intended to express the thermal comfort under certain conditions such as air temperature, relative humidity, wind speed, precipitation and thermal radiation, allowing more accurate evaluation of the environment Ávila et al. (2013).

In view of the adverse climatic conditions to which the animals are submitted, the constant improvement of the knowledge between the physiology of the animals and the to significant advances in animal bioclimatology, aiming the welfare of the animals and thus increase the productivity. The conditions of thermal comfort animal in a region can be assessed by information from meteorological databases and through geographic information system (GIS) technology that enable the generation of thematic maps, such as bioclimatic zoning, important for decision with respect to animal ambience.

In this context, knowledge of the environmental needs of the animals and climatic conditions of the main cities especially in animal production in the state, can contribute to the definition of technical and efficient building devices that make it possible to improve the thermal comfort of the animals and consequently the viability of its production in different regions of the state of Maranhão.

The aim of this study was to establish a bioclimatic zoning of the state of Maranhão, Brazil, and evaluate the viability for livestock production with regard to the question of thermal comfort.

MATERIAL AND METHODS

Climatological database generation

The state of Maranhão is located in northeastern of Brazil and it is divided into five regions: North, South, Central, East and West. Weather stations were chosen taking into account the greater amount of information available over the years, selecting thereby the São Luís (North), Carolina (South), Barra do Corda (Center), Caxias (East), Imperatriz and Zé Doca (West).

The climatological variables for the state of Maranhão were obtained through survey from the National Institute of Meteorology (INMET), the bank series of climatological historical data, covering the period 1961-1990.

The variables used were: average data air temperature (AT), relative humidity (RH) and atmospheric pressure (AP) which were used to estimate the WBT (Wet Bulb Temperature), BGT (Black Globe Temperature) and DPT (dew point temperature) with the aid of software *CYTSoft Psychrometric Chart* 2.2.®.

To determine the BGT, it was used the following equation:

$$BGT = - 0.9387 + 0.8562*DBT + 0.0162*DBT^2$$

Where:
BGT = Black globe temperature (ºC)
DBT = Dry bulb temperature (ºC)

Equations

Bioclimatic indices were determined by using mathematical equations implemented in Microsoft Excel®. The temperature and humidity index (THI) was determined according to the equation proposed by Thom (1959).

$$THI = DBT + 0.36 \times DPT + 41.2$$

Where:

DBT = Dry bulb temperature (ºC)
DPT = Dew point temperature (ºC).

To calculate the black globe temperature and humidity index (BGTHI), it was used the equation proposed by Buffington et al. (1981).

BGTHI = 0.72 (WBT + BGT) + 40.6

Where:
WBT= Wet bulb temperature (ºC)
BGT= Black globe temperature (ºC)

Maps Generation of BGTHI and THI

The maps with bands of values THI and BGTHI were generated for the municipalities under study according to the longitude and latitude of the meteorological station, inserting the index of thermal comfort found in the interval of 0.3 for each station, extrapolating to the adjacent regions using the method to approximate or interpolate data using the Kriging interpolation technique using the Surfer 8.0® program.

RESULTS AND DISCUSSION

The highest average temperature values were observed for the cities of Caxias, Imperatriz e Carolina. In relation to relative humidity higher values were found in the cities of São Luís, Zé Doca e Barra do Corda (Table 1).

THI and BGTHI values were obtained in the range from 74.1 to 75.8 and from 80 to 82.3, respectively, specialized as shown in Figure 1.

Considering only the warmer seasons of the year (September to May), the general average of the seven municipalities assessed for THI and BGTHI were 75.4 and 81.8, respectively, and the city of Caxias 76.2 recorded values and 82.9 for these ratios (Figure 2).

For each animal species, there is a range of environmental condition called thermal comfort zone, in which the animal has the best results with the lowest energy consumption and minimal effort of thermoregulatory mechanisms, enabling better food and fast growing conversion and may vary depending on their genetic makeup, age, sex, weight, diet and acclimation Tinôco (1998). In this context, the thermal comfort indices assist in the evaluation of environments based on variations of climate variables values, serve as indicators to quantify and qualify the thermal discomfort and animal welfare, and minimize the physiological damage to animals, improving productive performance Broom (1986).

According to Hahn (1985), to domestic animals in general THI values equal or below 70 indicate a condition of comfort, values between 71 and 78 is considered critical; between 79 and 83 indicates danger; and above 83 constitute emergency. To Lima et al. (2007), THI values equal or lower than 75 featuring normal, alert 75 to 78, danger to 79-83 and emergency when it is higher than or equal to 84.

Table 1. Average temperature (ºC), relative humidity (RH %), temperature and humidity index (THI) and Black Globe Temperature and Humidity Index (BGTHI) in Maranhão cities analyzed in the period 1961-1990.

Cities	Temperature (ºC)	RH (%)	THI	BGTHI
São Luís	26.1	84.9	75.8	82.2
Caxias	26.8	70.9	75.7	82.3
Zé Doca	26.2	79.7	75.5	81.9
Imperatriz	26.3	74.9	75.3	81.7
Carolina	26.1	72.8	74.9	81.2
Grajaú	25.4	77.0	74.5	80.5
Barra do Corda	25.1	77.4	74.1	80.0

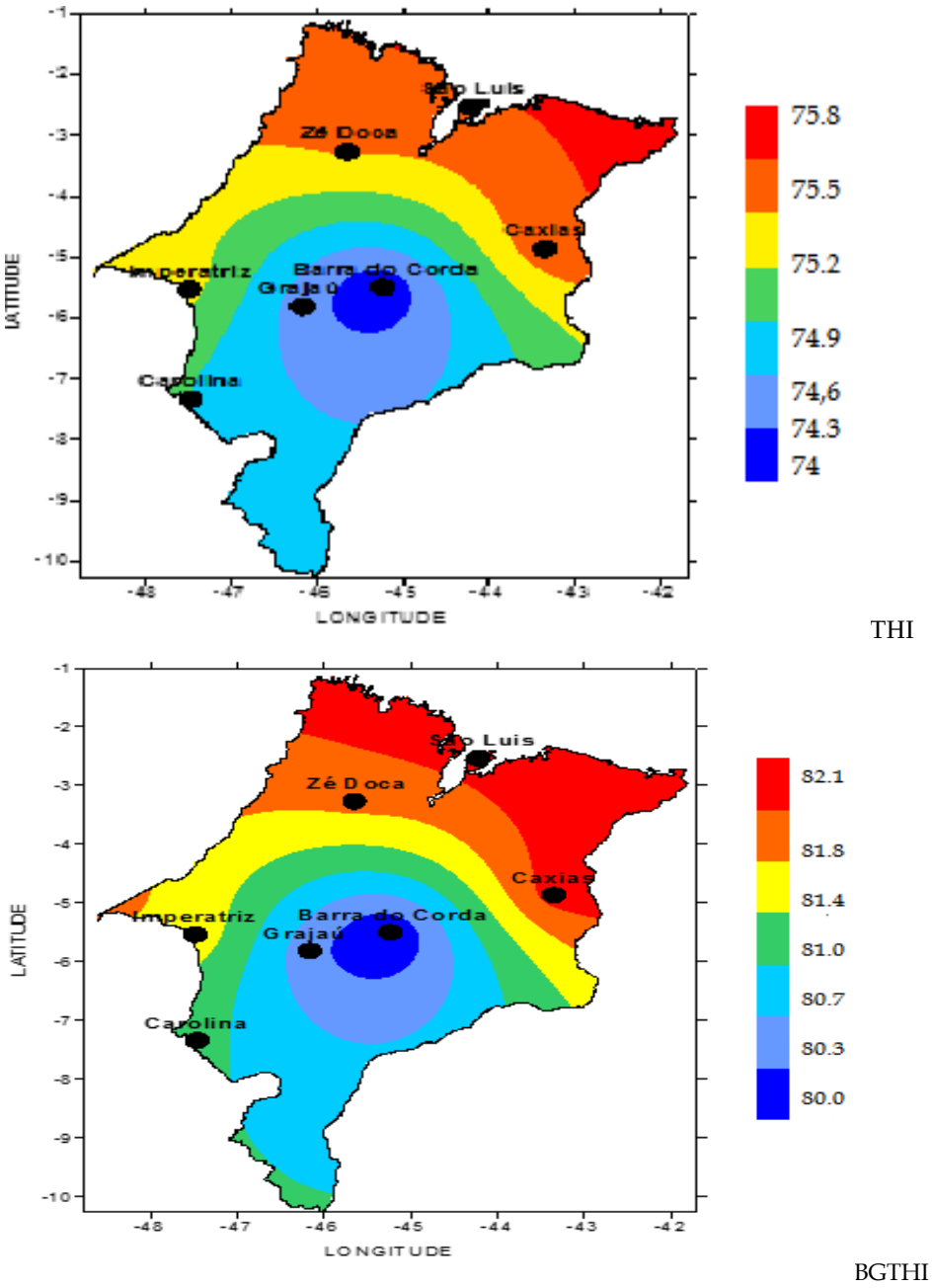

Figure 1 Spatial distribution of THI and BGTHI in the state of Maranhão, Brazil

Therefore, the average annual values of THI obtained for the evaluated municipalities present in the area concerned of comfort for the livestock according to Lima et al. (2007) (≤75) e critical (71-78) according to Hahn (1985). However, they not reached values classified as dangerous and emergency areas. According to Hah and Mader (1997), these values do not generally cause problems for healthy cattle, but may cause decrease in weight gain rate.

However, considering the physiological characteristics of each species, taking into account the specific thermal comfort ranges for each of them, allows a more accurate assessment of the environment and the welfare of animals.

According to Baêta (1997), BGTHI values between 74 and 78 characterize a state of alert and 79-84 a state of danger to cattle.

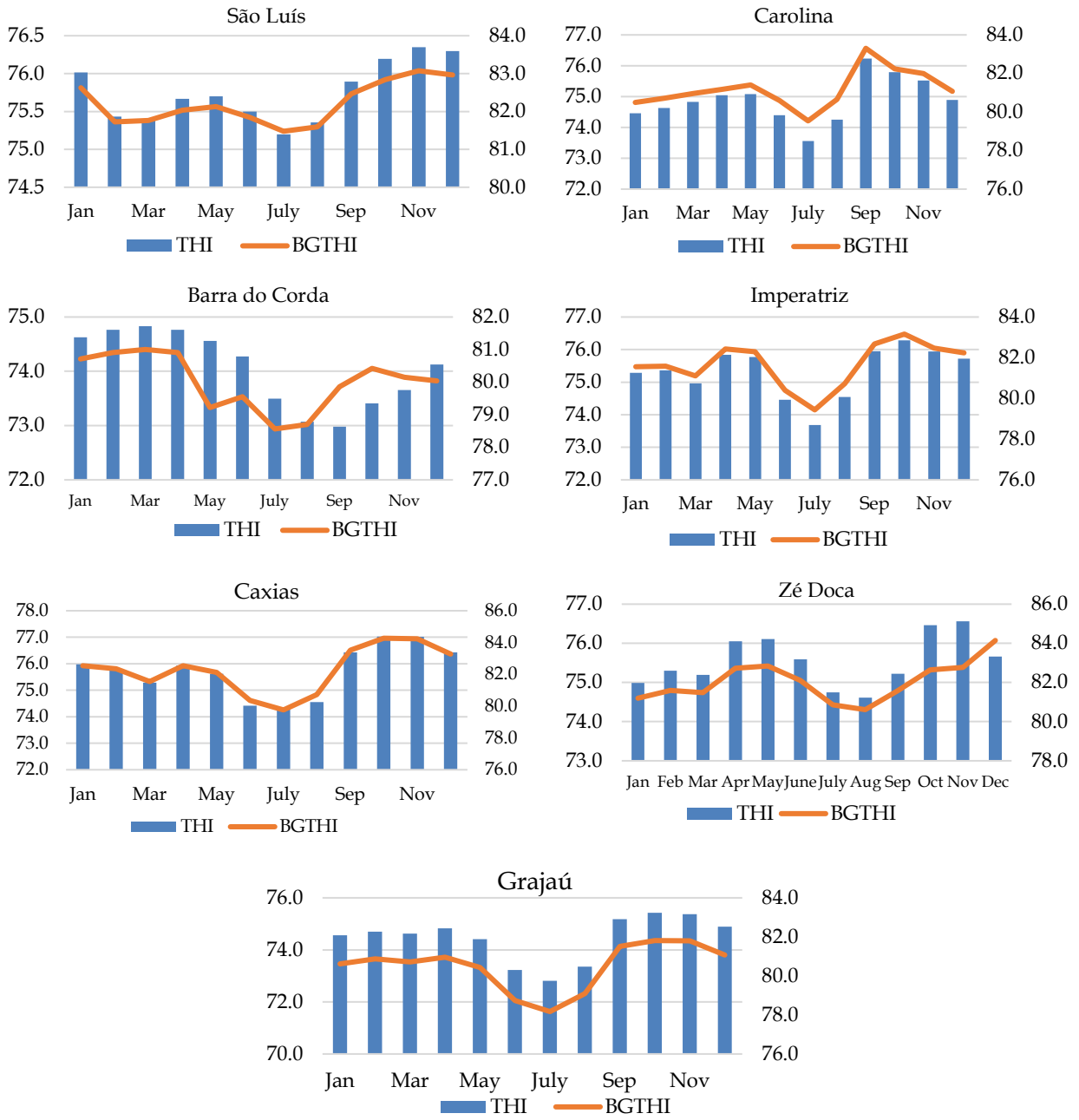

Figure 2 Monthly variation of THI and BGTHI of Maranhão cities in the period between 1961-1990.

Sales (2006) reports that THI values 61-65 are considered to thermal comfort for pigs and THI values 65-69 as warning and danger, and 69-73 emergency, being considered extreme thermal stress. For pigs, Turco (1997) suggests that the upper limit of thermal comfort for finishing pigs, based on BGHI, is equal to 72. According to the author, to higher values behavioral and physiological changes are observed, demonstrating the attempt to reestablish homeostasis.

Evaluating reproductive performance variables of sows subjected to different temperatures and relative humidity of air, Sales et al. (2006) found that THI values between 61 and 65 present a better comfort for the sows and between 65 and 69 for piglets, not being uncomfortable values for sows. Values between 69 and 73 provided discomfort for both sows and for their litter. The THI and BGTHI values obtained for all cities of the state of Maranhão evaluated were significantly higher than those recommended by these

authors, it can be considered as thermal stress zone for pig production.

For broilers, the temperature and humidity levels considered for comfort range according to weeks of life, and it is recommended values from 72.4 to 80 in the first week of life, 68.4 to 76 on the second week, 64.5 72 at third week, 60.5 to 68 on week 4 and 56.6 to 60 in the week 5 Abreu (2001). Thus, all bioclimatic zones analyzed showed only comfort for chickens in the first and second weeks of life, so it is necessary manipulations of the internal thermal environment for better welfare and productivity during the other phases.

The relative humidity is replaced importance in the thermal comfort of the birds when the ambient temperature reaches 25°C Silva (2007). High relative humidity rates associated to high temperatures, makes less moisture is removed from the airway, making breathing becoming rickety Tinôco (1998). Furtado et al. (2003) consider a comfortable environment with temperatures between 22 and 27°C and relative humidity between 50 and 70%, which is within the thermal neutral zone in which the birds are in perfect condition to express their best productive characteristics. Considering that the average annual temperature of the assessed cities remained above 25 ° C and the annual average RH was 76.8%, with maximum values of 84.9% for the city of São Luís, it can be inferred that the thermal comfort of the birds may be impaired in these regions, especially at certain times of the year (Figure 3).

BGTHI values above 75 for summer conditions, cause discomfort and worsening situation of stress in broiler chickens from 15 days old Tinôco (1988). According to Teixeira (1983) BGTHI values between 78.5 and 81.6 are suitable to weight gain and feed conversion to broilers between one and 14 days old, thus complying the Barra do Corda, Carolina and Grajaú municipalities, only at this stage of the production cycle. For broilers from 43 to 49 days old, BGTHI values between 73.3 and 80.5 reflected in a 41% increase in feed conversion and reduction of 37.2% in weight gain.

Considering the average values of BGTHI index obtained for all evaluated bioclimatic zones (80.0 to 82.3) and the recommended values for the various species in their different stages of production, it appears that the state of Maranhão has no natural conditions favorable to thermal comfort of the animals, and should be considered in the implementation of projects, the use of tools for correction of microclimate inside the premises. It is noteworthy that the constructive and climate strategies may vary depending on the type of climate (hot and dry or hot and humid). Up to an approximate limit relative humidity of 70%, the best way to refresh an environment is to make the use of water, since it has high heat capacity and high latent heat of vaporization. However, for regions with high relative humidity, as assessed in this study, other strategies can be adopted, such as those that are to increase the ventilation rate, through the addition of air renewal rate favoring heat loss through convection thus removing the heat produced by animals, to avoid excess temperature within the facility Nääs and Arcaro Júnior (2001).

Concerns about animal welfare are increasing in the public sphere. In this sense, animal production systems must provide adequate conditions of creation, to meet these market demands. In cattle production system to pasture for example, natural or artificial shading is a simple feature that contributes to the welfare provision of animals Martins (2001). As for poultry and swine production systems, modifications such as changing the height of the ceilings, side vents, louvers, afforestation and natural and artificial ventilation must be made in order to improve the thermal comfort of the internal environment of facilities for animal production Tinôco et al., (2002), besides the use managements which modify and enhance heat loss , as changes in the ambient heat load, increased heat exchange surface for the animals, reducing the radiant heat and convective and evaporative favoring loss Flamenbaum et al., (1986).

Animal interaction and environment must be considered when seeking greater efficiency in livestock farming, as the different responses of the animal to the peculiarities of each region are crucial in the success of the activity. Thus, the correct identification of the factors that influence the productive life of the animal, allows adjustments in management practices in production systems, enabling deliver sustainability and economic viability. The knowledge of climate variables, their interaction with the animals and behavioral, physiological and productive responses are crucial in adapting the production system to the activity goals Neivaet al. (2004). Production systems need investment in measures to promote the correction of microclimate, to establish optimal levels of thermal comfort for the animals.

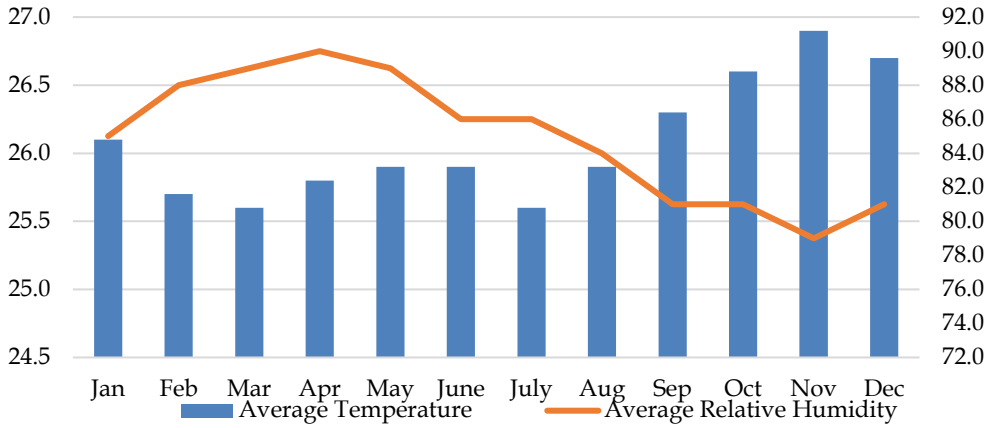

Figure 3. Average monthly temperature values (º C) and relative humidity, in São Luís, Brazil.

CONCLUSION

Among the seven regions evaluated, none presented adequate comfort indexes for animal production with satisfactory productive indexes. The studied regions present low activity in the poultry and pig sectors. Intensive confinement systems with high ambience requirements

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