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ORIGINAL ARTICLE

Enthalpy as a thermal comfort index in broiler poultry production[1]

Entalpia como índice de conforto térmico na produção de frango de corte

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HIGHLIGHTS:

Attention to heating management during the first and second weeks of poultry rearing is crucial.
Attention should be directed towards cooling management during the third week of broiler chickens rearing.
Enthalpy is important to support environmental management practices in broiler buildings.

ABSTRACT: Enthalpy is currently suggested as a suitable index for assessing the internal environment of poultry production, primarily dependents on air temperature and relative air humidity. This study aimed to analyze enthalpy in bird production in Londrina, located in the northern region of Paraná, Brazil, and to model the comfort enthalpy required for enhanced production efficiency. Data from 1961 to 2021 from the Instituto Nacional de Meteorologia (INMET), Brasília, Federal District, Brazil, were utilized to compare the thermal comfort conditions and critical limits set for the birds. The meteorological data from this period were scrutinized to understand their variations and interrelationship through a descriptive study and correlation analysis of different parameters. The research findings, based on the enthalpy indices derive historical averages, suggest that heating is crucial for birds during the first and second weeks of housing, during the winter, given the location's low temperatures. For birds housed during the third to sixth weeks of age, the enthalpy indices indicated the necessity of cooling systems.

Key words: ambience, animal welfare, thermal stress, cutting poultry, climatic extremes

RESUMO: A entalpia tem sido proposta atualmente como um índice adequado para a avaliação do ambiente interno de galpões de frangos de corte, pois depende basicamente da temperatura e da umidade relativa do ar. Dessa forma, objetivou-se analisar a entalpia como índice de conforto térmico na produção de aves para o município de Londrina, Paraná, e modelar a entalpia aos índices de conforto térmico que proporcionam eficiência na produção. Para o estudo, utilizaram-se dados de 1961 a 2021 do Instituto Nacional de Meteorologia (INMET), de Brasília, Distrito Federal. Os dados meteorológicos desse período foram analisados para conhecer suas variações e as relações entre eles, através de um estudo descritivo e de correlação entre diferentes parâmetros, para comparar as condições de conforto térmico e os limites críticos estabelecidos para as aves. Com base nos resultados desta pesquisa, considerando os índices de entalpia obtidos através de médias históricas, pode-se concluir que a utilização de aquecimento para as aves na primeira e segunda semanas de alojamento, no período de inverno, considerando o local estudado, é imprescindível, devido às baixas temperaturas registadas. Para aves alojadas na terceira, quarta, quinta e sexta semana de idade, considerando os índices de entalpia, pode-se concluir que é necessária a utilização de sistemas de resfriamento para as aves.

Palavras-chave: ambiência, bem-estar animal, estresse térmico, avicultura de corte, extremos climáticos

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Introduction

Since 2019, Brazil, and specifically the state of Paraná, has emerged as the largest exporter of poultry production (MAPA, 2020). It accounts for 35.51% of the production and slaughter of poultry for import. The municipality of Londrina contributes significantly to this figure, being responsible for 20.05% of the production. This is facilitated by its 11 slaughterhouses, 7 hatcheries, and 1830 poultry houses (SINDIAVIPAR, 2020).

Heat stress, which can induce physiological issues and impact the endocrine and respiratory systems as well as the electrolyte balance of birds, is linked to the development and productivity of farms (Harada et al., 2021).

Abreu et al. (2015) asserted that birds require a suitable environment to achieve their productive potential. Consequently, maintaining a thermal environment within the bounds of environmental comfort is crucial for the realization of this potential.

Correia & Oliveira (2019) asserted that the calculation of enthalpy change can determine whether a reaction is exothermic (releasing heat) or endothermic (absorbing heat). For broilers to reach their productive potential in an environment with a temperature within the enthalpy of comfort, they require an appropriate range of temperature and relative air humidity. This is particularly crucial during the reproductive phases. Additionally, the method and management of rearing, shed density, and the intensity of environmental thermal regulation must be considered. Harada et al. (2021) suggested that the enthalpy index, which incorporates temperature, relative air humidity, and atmospheric pressure, can be used to classify the indices of animal discomfort and ambience. These environmental variables are typically available in meteorological stations.

The aim of this study was to examine the role of enthalpy in avian production in Londrina, located in the northern region of Paraná, Brazil. Furthermore, the study sought to develop a model for the comfort enthalpy required by these birds to enhance production efficiency.

Material and Methods

A historical analysis of climatological data, including compensated air temperature (average temperature), relative air humidity, and precipitation, was conducted for the municipality of Londrina in the state of Paraná, Brazil. Londrina is situated at an altitude of 550 m, with latitude coordinates ranging from 23º 08’ 47” to 23º 55’ 46” S and longitude coordinates from 50º 52’ 23” to 51º 19’ 11” W. The data were sourced from the Instituto Nacional de Meteorologia (INMET) in Brasília, Federal District, Brazil. The study utilized a historical series of available data from 1961 to 2021, through which the specific enthalpy index of the air was examined.

The specific enthalpy index of air (kJ per kg per dry air) was calculated using an equation initially proposed by Albright (1990) and later adapted by Rodrigues et al. (2010). This equation allows for the direct incorporation of temperature, relative air humidity, and local atmospheric pressure values. For the climatic assessment of broiler production in Londrina, the recorded minimum, average, and maximum temperatures were utilized as parameters in the enthalpy calculation. This calculation is represented in Eq. 1.

$$h = 1.006 \cdot Ts + \frac{RH}{\rho_B} \cdot 10^{\frac{7.5 \cdot Ts}{237.3 + Ts}} \cdot \left(71.28 + 0.052 \cdot Ts\right) \qquad (1)$$

where:
- h - enthalpy (kJ per kg per dry air);
- Ts - dry bulb temperature (°C);
- RH - relative air humidity (%); and,
- ρ_B - barometric atmospheric pressure (mm Hg).

The following symbology was adopted to compare the needs of birds with the climatic conditions of Londrina city: ECI represents critical enthalpy lower than what the birds require; EC signifies the enthalpy of comfort required by the birds; ECS denotes critical enthalpy higher than what the birds need. These values were utilized to assess the thermal comfort conditions and critical limits set for birds, based on their age in weeks.

Results and Discussion

The intensive rearing system’s environment directly impacts animal comfort and welfare. It creates challenges in maintaining thermal balance within the facilities and inhibits the expression of natural behaviors, thereby affecting the birds’ productive performance (Nazareno et al., 2009).

Souza et al. (2015) characterized bird welfare as a state of harmony between the birds and their environment. Birds are sensitive to extreme temperatures, experiencing significant losses that are not only productive but also economic. These losses are particularly pronounced in the final stages of production. Heat stress, a primary factor contributing to increased mortality, compromises their comfort and well-being.

The thermoneutrality zone pertains to an optimal thermal environment where birds can exhibit their highest productive traits. In this regard, assessing various broiler breeding systems is crucial to characterize the thermal environment and identify the variables impacting the production system. This evaluation aids in determining conditions conducive to optimal performance, using welfare indicators as a response to the breeding environment (Nazareno et al., 2009).

The importance of environmental quality is escalating, with factors like ventilation and humidity, which directly influence air and litter quality, requiring control throughout the rearing period until the age of slaughter. Numerous studies have shown that elements such as temperature, relative air humidity, and air velocity assist birds in heat dissipation, thereby aiding them in maintaining their comfort enthalpy (Harada et al., 2021).

Andrade et al. (2018) posited that optimal bird productivity is achieved in farms that meet welfare requirements, thereby promoting the birds’ physical and mental health as well as thermal comfort.

Of the various thermal comfort evaluation indicators examined, enthalpy is suggested as the most appropriate for assessing the environment within a broiler shed. This is primarily attributed to its dependence on air temperature and relative air humidity. Enthalpy signifies the quantity of energy in the environment and provides easy access to the necessary variables for computation, thereby facilitating its use by producers (Faustino et al., 2021). Consequently, analyzing the lower and upper comfort and critical enthalpy indices is crucial, as they are significant variables for bird productivity and animal welfare.

Table 1 presents data on comfort enthalpy, lower and upper critical enthalpy in relation to the age of the birds, measured in weeks. Evidently, the enthalpy values were higher during the initial weeks, decreasing towards the end of the birds' lives. This indicates that the thermal comfort zone exhibits higher temperatures in the first week, which gradually decrease by the seventh week, demonstrating a declining trend.

In addition to determining comfort enthalpy, the formula's outcome also categorizes the life cycle of birds. As stated by Faustino et al. (2021), the comfort variables for broilers fluctuate weekly, necessitating different conditions of temperature and relative air humidity for these animals each week.

Table 1 presents the weekly ECI, EC, and ECS values throughout the bird's life cycle, from the day of delivery to the producer until its dispatch for slaughter at seven weeks. Notably, these values exhibited a decreasing trend over time, with identical figures recorded in the 6th and 7th weeks of the birds' life cycle.

Table 2 presents 60 years of climatological data for the city of Londrina. The analysis of data reveals that the highest temperatures occured during the summer months (December to March), with maximum temperatures generally falling below 30.5 °C. The lowest temperature recorded was 11.60 °C in July, during the winter months.

The average minimum temperature during summer was 20.2 °C, which drops to an average of 12.8 °C during the colder months. In spring and autumn, the average minimum temperature ranged between 13.42 – 17.88 °C. The RH remained approximately 74.02% throughout the year, peaking at 85.62% in April and dipping to 67.17% in September.

The average enthalpy index for summer stood at 59.12 kJ per kg per dry air, while for winter it was 41.88 kJ per kg per dry air. These figures suggest that to maintain the EC and prevent stress in birds, both in ECI and ECS, the use of air conditioners and humidifiers is essential to regulate the EC level within the average enthalpy.

Figure 1 illustrates the climatic analysis for broiler production in Londrina city, using recorded temperatures as variables for enthalpy calculation. The figure emphasizes the enthalpy of thermal comfort over the first six weeks of the life cycle.

During the initial two weeks of a bird's life cycle, temperatures throughout the year fell within the ECI range, as depicted in Figures 1A and B. The EC threshold was achieved only in the third week of the life cycle, specifically during the months of December, January through March. Conversely, from April to November, temperatures remained within the ECI range. In the fourth week, temperatures fell within the EC range only during April, October, and November. From December to March, temperatures shifted to the ECS range, while from May to September, they reverted to the ECI range. During the fifth week, average temperatures from May to October were within the EC range, whereas from November to April, they fell within the ECS range. In the sixth and seventh weeks, the EC range was observed from May to September, with temperatures in the remaining months falling within the ECS range.

The results indicate that during the first week of the avian life cycle, the EC was achieved between December and April, coinciding with the summer season. From May to November, the enthalpy indices consistently fell within the ECI range. In the second week, the EC was only observed in October and November, with the remaining months registering indices in the ECS range. During the third week, the EC was present from May to September, while the indices for the other months fell within the ECS range. From the fourth to the seventh week, all indices were consistently within the ECS range, rendering the development and production of broilers unfeasible without measures to maintain the EC.

During the initial four weeks of the birds' life cycle, the EC index was only recorded in the fourth week, specifically in December, while the remaining indices were recorded in ECI. From the fifth to the seventh week, EC indices could be found from January through April. Additionally, in the fifth week, an EC index was recorded in November, while in the

Table 1. Values considered for lower critical enthalpy (ECI), comfort enthalpy (EC) and upper critical enthalpy (ECS), depending on the age of the birds

Age (weeks)	ECI	EC	ECS
	(kJ per kg per dry air)		
1	51.9-76.9	77.0-88.0	88.6-145.8
2	42.8-66.8	67.2-76.8	77.3-121.3
3	40.7-57.5	57.8-66.9	80.7-115.8
4	38.6-49.0	49.5-57.2	57.8-110.5
5	36.6-39.5	39.7-54.1	55.1-105.6
6	34.7-37.2	37.4-51.7	52.2-100.4
7	34.7-37.2	37.4-51.7	52.2-100.4

Source: Adapted from Barbosa Filho et al. (2007)

Table 2. Minimum, average, and maximum values for the temperature and for enthalpy and relative air humidity (RH) throughout the year

Months	Temperature (°C)			Enthalpy (kJ per kg per dry air)			RH
	Minimum	Average	Maximum	Minimum	Average	Maximum	(%)
January	19.76	24.23	30.10	47.34	60.46	81.53	76.83
February	19.70	24.30	30.40	46.90	60.30	82.18	76.03
March	18.84	23.57	30.32	44.29	57.62	81.24	75.13
April	16.60	21.70	28.40	41.73	56.27	80.27	85.62
May	13.42	18.46	25.19	31.24	43.07	62.58	74.62
June	12.08	17.09	23.78	29.14	40.69	59.69	78.04
July	11.60	16.98	24.13	27.20	39.14	58.80	73.76
August	12.90	18.95	26.46	28.56	42.03	63.12	67.81
September	14.66	20.48	27.46	32.08	45.66	66.01	67.17
October	16.68	22.09	28.70	37.17	50.81	71.52	69.36
November	17.88	23.26	29.75	40.16	54.34	75.62	69.90
December	22.53	23.91	29.93	54.06	58.13	78.95	73.96

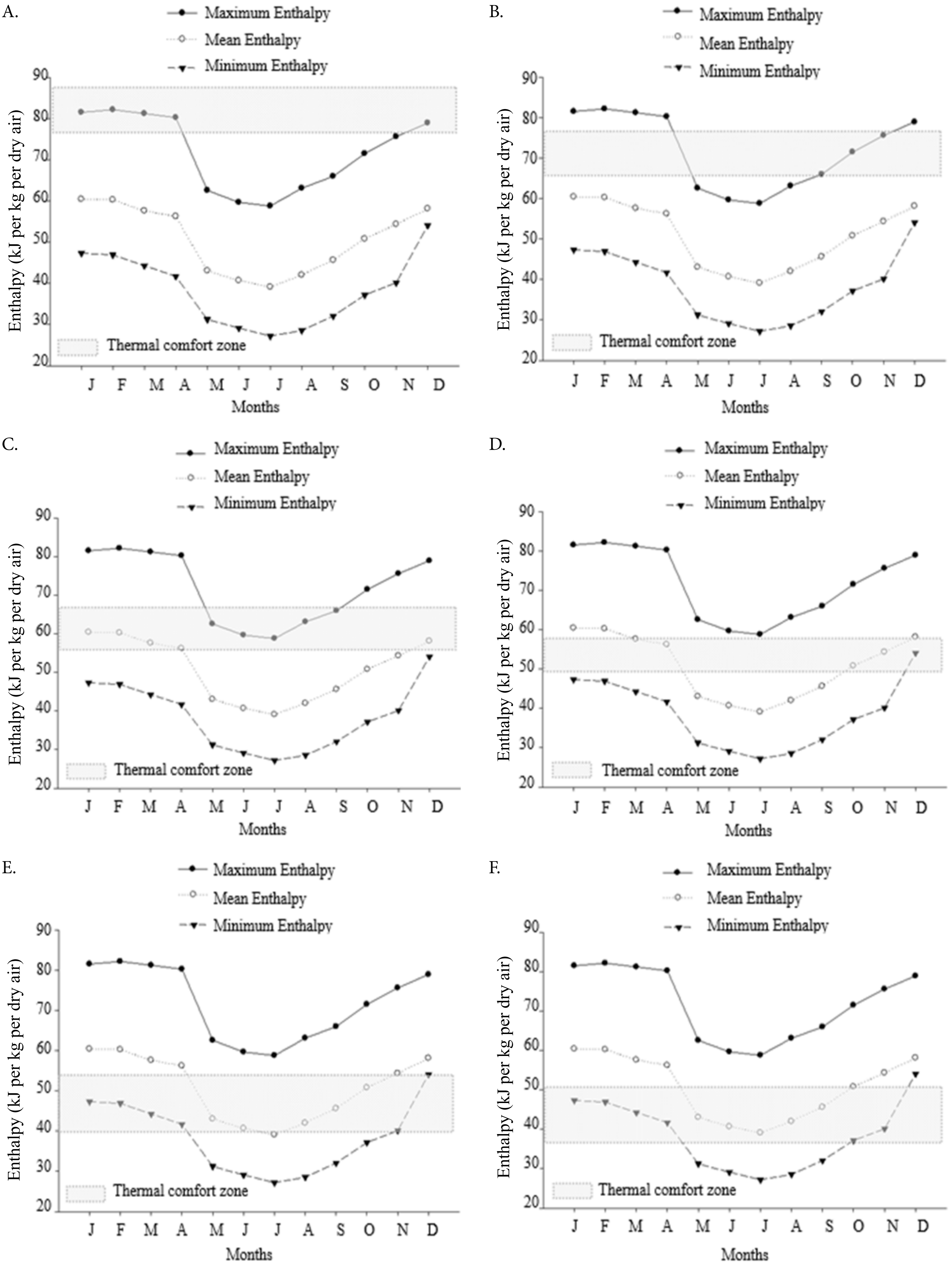

Figure 1. Thermal comfort enthalpy in relation to maximum, average, and minimum enthalpies throughout the year in the first stage of poultry creation (first week) (A), second stage of poultry creation (second week) (B), third stage of poultry creation (third week) (C), fourth stage of poultry creation (fourth week) (D), fifth stage of poultry creation (fifth week) (E), and sixth stage of poultry creation (sixth week) (F)

sixth and seventh weeks, EC indices were recorded in both October and November.

The findings suggest that broiler farms must equip their sheds with technology that enables ambient temperature control, ensuring the EC index is maintained throughout the year. The weekly life cycles of the birds fluctuate each month, and without heating, cooling, and humidification technology, it becomes unfeasible for the producer to achieve a higher percentage of uniformity in birds ready for slaughter at the end of the seven-week cycle.

Coelho et al. (2019) suggested that once the optimal ambient temperature for birds is determined, efforts should be made to utilize tools that closely mimic the conditions of an environment with an EC index. This is to enhance their physiological responses and overall performance. These tools should promote the rational use of resources, facilitate savings, and expedite the birds' development.

In this scenario, the typologies of buildings can exert a direct influence on the regulation of climatic variables that dictate the site's enthalpy. As Brito (2020) asserted, there is no universally standardized project model intended for the environmental comfort of animals that can be applied across all locations, due to the varying climatic conditions in different regions.

Gonçalves et al. (2022) asserted that a building's roof serves as the primary shield against direct sunlight exposure. Therefore, it is crucial to employ a range of techniques that furnish the poultry building with an appropriate microenvironment for the birds.

Investing in alternative insulating materials for bird enclosures in tropical climates is deemed significant, as the majority of radiant heat is derived from these coverings.

Hence, utilization of materials with lower thermal conductivity than that of traditional ones are preffer. In this regard, Brito et al. (2020) underscore the significance of integrating building materials and design elements in the construction of structures intended for broiler chicken rearing. This approach takes into account the local climatological characteristics of the proposed project site, with the goal of achieving enhanced mitigation of the internal environmental temperature. This variable is factored into the enthalpy index calculation.

Conclusions

1. In the location under study, the use of heating during the first two weeks of bird housing in winter is crucial owing to the low temperatures recorded.

2. Considering the enthalpy indices for birds housed during their third, fourth, fifth, and sixth weeks of age, implementing cooling systems is important for their well-being.

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