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Original Article

Thermal Response of Three Strains of Hens Housed in a Cage-Free Aviary at the Amazon Rainforest

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ABSTRACT

This study aimed to evaluate the thermal response of three strains of hens housed in a cage-free system at the Amazon rainforest in order to evaluate how feather coverage influences thermal exchange with the environment. The experimental method was completely randomized and treatments comprised three strains of hens (Rhode Island Red (red feathers with feathers on the neck), alternative strain FCI (red feathers without feathers on the neck), and alternative strain FCIII (white feathers without feathers on the neck)), with 20 hens (replicates) analyzed per strain. Thermal images of each bird were captured in order to record the birds' surface temperatures on five points in five targets. All data collected in this study were subjected to ANOVA and subsequently to the Tukey test at $p \leq 0.01$ and $p \leq 0.05$. The aviary's left wall presented a lower average temperature, indicating lower heat accumulation, while the floor presented higher heat accumulation. FCIII hens (white feathers) presented higher ($p<0.05$) heat accumulation on the head and legs, and lower ($p<0.05$) heat accumulation on the neck and back in relation to other analyzed hens, indicating increased heat exchange efficiency and high concentration of this process in specific body areas. FCI and FCIII hens (without feathers on the neck) presented lower ($p<0.05$) heat accumulation on the neck and higher ($p<0.05$) heat accumulation on the head and legs, indicating that the feather coverage directly influenced heat exchange mechanisms, and an increased area without feathers provided great heat exchange zones for birds in a tropical climate.

INTRODUCTION

The Amazon rainforest is an important regulatory mechanism of the tropical atmosphere and its climate variation, performing important functions in the climate equilibrium of several ecosystems and their inhabitants. The region also has unique climate and environment characteristics (Fisch *et al.*, 1998). The development of poultry production in the region thus presents several challenges related to birds' environmental comfort, depending on the type of housing system used and birds' response to these environmental characteristics (Cruz *et al.*, 2016).

Chickens are homeothermic animals, being directly affected by climate changes (Kolb, 1984; Cunningham, 2004). They are in continuous thermal exchange with the environment, characterizing an interaction between environmental factors and birds' physiology. However, this mechanism is effective only when the bird's temperature presents disequilibrium in relation to the environment (Abreu & Abreu, 2011). Thus, changes in the birds' physiological mechanism caused by environmental conditions may affect performance responses (Bueno & Rossi, 2006).

Similar to other species, birds' thermal comfort zone may be defined as a range of temperatures where the metabolic rate is minimal and energy needs are low (Nascimento *et al.*, 2014). Birds' ability to dissipate heat tends to decrease as ambient temperature and relative humidity leave the thermoneutral zone (air temperature at 24°C (75.2 ºF) and relative air humidity at 70%). In this sense, significant changes in the bird's body temperature cause caloric stress (Yahav *et al.*, 2005; Curto *et al.*, 2007; Slimen *et al.*, 2015).

Such caloric stress imposed by excessive heat is the great barrier faced by the poultry industry when trying to reach an ideal condition of animal welfare in tropical regions, especially considering the control of environmental conditions within and outside of the aviary, among other factors (Tinôco, 2001). It is known that the poultry industry had significant changes to its animal welfare protocols along the last decades, mainly adopting alternative management systems such as free-range, cage-free, agroecological, and organic. In this context, there are a lot of management protocols that should be studied and improved to provide data regarding birds' adaptability to their environmental conditions and how adaptability may affect bird performances (Al-Ajeeli *et al.*, 2018). As a model to provide a better environmental condition to birds, the cage-free aviary system is highly variable, and needs to present adequate management practices and design. But this system may provide the birds with a good environmental condition, free of behavioral restriction and stress problems, with an efficient heat exchange with the environment (Hartcher & Jones, 2017).

Studies of birds' thermal response are important to provide the poultry industry with data regarding its adaptability to environmental conditions and how these effects may affect bird performances. Considering these aspects, this study was developed to evaluate the thermal response of three strains of hens housed in a cage-free system in the Amazon rainforest, in order to evaluate the feather coverage's influence on the thermal exchange with the environment.

MATERIAL AND METHODS

This study was conducted in the facilities of the Poultry Sector, Faculty of Agrarian Sciences, Federal University of Amazonas, Manaus, Amazonas State, Brazil. Animals' management procedures followed the guidelines established by the Ethics Committee in Animals' Use of the Federal University of Amazonas.

The aviary was located on the following geographic coordinates: latitude 3° 06′ 14″ S, longitude 59° 58′ 46″ W, at an altitude of 92 m. The climate in the region was classified as humid tropical, presenting an annual rainfall of 2,286 mm, temperature ranging between 27 and 32 °C, and relative air humidity between 65 and 75% (Rufino & Martorano, 2020). According to Martorano *et al.* (2017), it is possible to identify variations with three patterns (Af_1, Af_2, and Af_3) in the state of Amazonas, but in Manaus the typology Af_3 predominates. The aviary (25 x 8 m) was built east-west and divided into 14 pens (3 x 3 m). The floor was covered with 8 cm of sawdust, presenting cement roof tiles, open skylights for natural ventilation and illumination, with no curtains or forced ventilation. The birds were already housed in the aviary before analyzes were carried out.

The experimental method was completely randomized and treatments were comprised three strains of hens Rhode Island Red (red feathers with feathers on the neck), alternative strain FCI (red feathers without feathers on the neck), and alternative strain FCIII (white feathers without feathers on the neck)), with 20 hens (replicates) being analyzed per strain. Hens (60 weeks-of-age) were housed at a density of 4 birds/m^2 and fed diets formulated according to the requirements proposed by Rostagno *et al.* (2017), with food and water available *ad libitum*.

The data were collected in two periods (9:00 a.m. and 4:00 p.m.) using a FLIR® infrared thermographic camera, with a window of one hour for data collection. Thermal images of 10 points of the aviary's roof, walls (right and left in the east-west way), and floor were initially captured to evaluate its environmental conditions. In order to record the birds' surface temperatures, thermal images of randomly selected birds were captured for the following targets: (i) head; (ii) neck; (iii) back, (iv) wing and (v) legs. The temperature was evaluated on five points for each target (Figures 1 and 2). Based on the results obtained in the FLIR® software for thermographic images' processing, the Average Surface Temperature (AST) was calculated according to the equation proposed by Richard (1971).

All data collected in this study were analyzed using the GLM procedure of SAS (Statistical Analysis System, v. 9.2) and estimates of the strains were subjected to ANOVA and subsequently to the Tukey test. Results were considered significant at $p \leq 0.01$ and $p \leq 0.05$.

RESULTS AND DISCUSSION

Thermal condition results inside the aviary showed that the left wall presented a lower temperature, which may be associated with the aviary architecture in the east-west direction, thus providing less exposure to the sun on this side (Table 1). In contrast, the floor presented

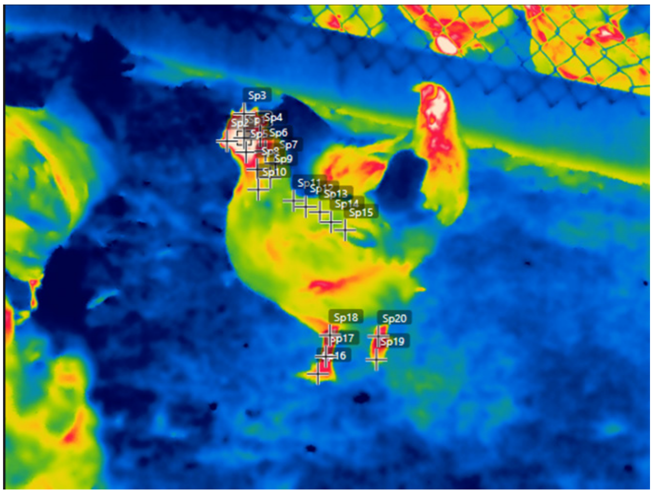

Figure 1 – Thermal image of a Rhode Island Red hen indicating the evaluated targets.

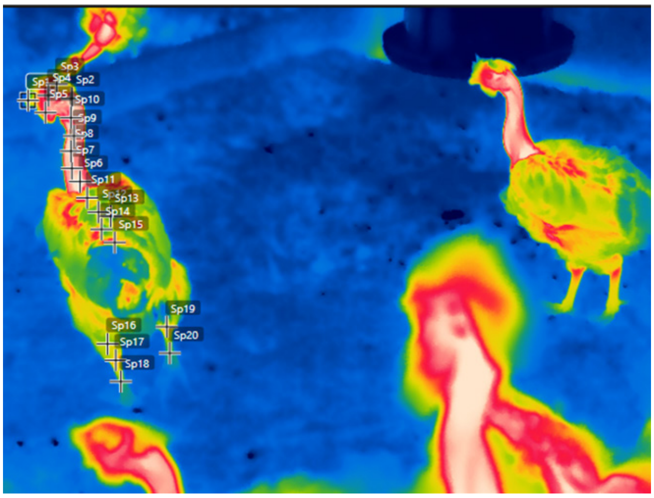

Figure 2 – Thermal image of a FCIII hen indicating the evaluated targets.

both high temperature accumulation and variation in temperature. These results may be associated with the birds' presence and distribution along the aviary and the variation in the concentration of the sawdust used to coat the floor where the birds were housed. Even though all pens have the same number of birds per m^2, variations in sawdust height and distribution along each pen may occur.

Table 1 – Thermal response of the aviary used to house the birds.[1]

Place	Average Temperature (ºC)	Min. Temperature (ºC)	Max. Temperature (ºC)
Roof	28.14±0.11	28.00	28.30
Right wall	28.04±0.13	27.90	28.20
Left wall	27.94±0.08	27.80	28.00
Floor	28.88±0.71	28.00	29.60

[1] Mean values ± SE are presented.

As expected, the roof tended to present a higher temperature accumulation due to its direct exposure to the birds. However, the studied location had a great number of trees along its edge, creating a good microclimate that resulted in lower heat accumulation in aviary structures.

In Brazil, for economic reasons or lack of information, little attention is given to aviaries' architectural planning and design, or to structures that are compatible with each region's climatic reality. As a consequence, the aviary can be very hot in the summer, resulting in almost continuous thermal discomfort for the birds (Tinôco, 1995). Both the Amazon environment and the internal conditions of the aviary housing environment directly affect the birds' comfort and thermal experience. This impacts the maintenance of thermal balance inside the facilities and the hens' natural behavior expression (Nazareno *et al.*, 2009).

The management of aviary structures and environmental conditions are important to provide comfort for the birds (Näas *et al.*, 2007). Diseases and injuries are usually developed due to inadequate conditions in the aviary, which are the major causes of carcasses abnormalities in slaughterhouses (Pinto *et al.*, 1993). Perdomo (1998) reported that acclimatization issues tend to cause serious problems for the broilers, suggesting that the use of simple thermal diagnosis methodologies for aviary structures and broilers may provide data and enable responses that solve a lot of problems in bird management.

Hens with white feathers presented higher temperature accumulation on the head and legs, and lower temperature accumulation on their neck and back (Table 2). Previous studies showed that feather color directly affects birds' thermal comfort (Scarinci

Table 2 – Birds' thermal response in different body targets.

Strains	Variables			
	Head (ºC)	Neck (ºC)	Back (ºC)	Leg (ºC)
Rhode Island Red	36.14±0.38^b	39.88±0.91^a	31.50±2.39^b	32.30±0.85^b
FCI	36.76±2.23^{ab}	39.48±0.96^{ab}	34.18±3.29^a	32.38±1.17^b
FCIII	37.12±1.45^a	32.07±1.77^b	29.99±0.76^c	35.54±2.02^a
p-value	0.03**	0.01*	0.01*	0.01*
CV (%)	3.29	4.28	4.12	2.45

CV – Coefficient of Variation. * Significant Effect ($p \leq 0.01$). ** Significant Effect ($p \leq 0.05$).

& Marineli, 2014), as they are responsible for body heat absorption and accumulation. Fragata *et al.* (2015) reported that surfaces with high absorptivity in the heat wavelength range tend to reach higher equilibrium temperatures than those with less absorptivity. Thus, dark color surfaces absorb 50% more incident heat than white surfaces (Kreith, 1973).

Furthermore, it was observed that birds without feathers on the neck presented lower temperatures on the neck and high temperatures on the head and legs, indicating a direct relation between feather cover and heat accumulation. Lack of feathers on the neck indicated great heat dissipation along this surface and concentration of heat on the head and the legs, regions that present high heat accumulation, in spite of mechanisms to dissipate this heat (Deschutter & Leeson, 1986).

The head, neck, and some areas around the abdomen have a naturally poor feather coverage as compared to other regions of the hens, causing heat accumulation and creating zones with more sensibility to this heat flow (Li & Yamamoto, 1991; Choi *et al.*, 1997; Naas *et al.*, 2010). Hens with low feather coverage tend to present a more efficient natural capacity of exchanging heat with the environment than other strains, especially due to their mechanisms of metabolic rate control being most effective and their own thermoregulation (Deschutter & Leeson, 1986). Feathers play a critical role in heat accumulation and dissipation, directly affecting the hens' productivity (Leeson & Morrison, 1978; Deschutter & Leeson, 1986).

The average surface temperature results showed that birds without feathers on the neck presented lower (p<0.05) heat accumulation, especially the alternative strain FCIII, which combines the absence of feathers on the neck and white colored feathers. These results may indicate these birds' greater capacity of dissipating heat (Table 3).

Table 3 – Average thermal response of birds' surfaces.

Strains	Temperature (ºC)
Rhode Island Red	44.37±1.69[a]
FCI	42.71±3.02[b]
FCIII	41.31±1.06[c]
p-value	0.01*
CV (%)	4.33

CV – Coefficient of Variation. * Significant Effect (p≤0.01).

Based on these results, we suggest that a larger area available for heat exchange with the environment improves birds' thermal comfort; and birds without feathers on the neck have an increased area to perform this heat loss. It is therefore important to point out that two major points should be considered when analyzing the influence of animal welfare in bird handling: a) feather coverage is related to the bird's accumulation of body heat and its heat exchange with the environment; and b) blood flow is related to the body's heat production (Yahav *et al.*, 2004; Silva *et al.*, 2007; Marchini *et al.*, 2018).

According to Nascimento *et al.* (2011), heat loss is related to specific feather coverage in each body part. Fukayama *et al.* (2005) also reported that feather coverage in specific places may provide an extension of the heat loss surface, improving the thermal comfort range of the birds and allowing for some strains to better adapt to temperature ranges rather than others. In this sense, Yahav *et al.* (1998) reported better adaptation to tropical climates by chickens without feathers in the neck, precisely due to this extra heat dissipating region on the neck.

Other studies still point out that modern strains' feather coverage along most of the body surface led to the development of a greater heat sensibility, creating more efficient mechanisms to detect environmental heat changes and concentrate heat exchanges in specific body areas, (especially those without feathers) such as shanks, feet, neck (in some strains) and so on (Cangar *et al.*, 2008; Naas *et al.*, 2010; Abreu & Abreu, 2011).

On the other hand, blood flow is the major responsible for regulating homeostasis processes (Yahav *et al.*, 2001; Yahav *et al.*, 2004; Cangar *et al.*, 2008; Marchini *et al.*, 2018). If the environmental temperature is higher than the body temperature, blood flow tends to decrease in order to reduce the body's heat production. However, if the environmental temperature is lower than body temperature, blood flow tends to increase in order to increase the body's heat production (Richards, 1971; Tessier *et al.*, 2003; Shinder *et al.*, 2007; Naas *et al.*, 2010).

Thus, great variations in the environmental temperature (high or low) and a inefficient body heat exchange by the birds tend to negatively impact the performance, carcass and noble cut yields. These losses may be represented by reduction of feed intake (from 12% to 28%) and weight gain (from 18% to 44%), consequently affecting energy retention, protein and fat deposition in the carcass, and viscera growth (Abu-Dieyeh, 2006; Al-Fataftah and Abu-Dieyeh, 2007; Mello *et al.*, 2015; Marchini *et al.*, 2018).

CONCLUSIONS

Birds without feathers on the neck housed in a cage-free system presented lower body heat accumulation, especially on the neck, indicating this region to be a great zone for heat exchange and the creation of better thermal comfort conditions. Birds with white color feathers also presented lower body heat accumulation.

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