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Evaluation of Heat stress Impact on Coat Color pattern and physiological responses of West African Dwarf goats in South Western Nigeria

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Abstract

This study evaluated the impact of heat stress on different coat color patterns and the associated physiological responses of West African Dwarf (WAD) goats in South-Western Nigeria. Thirty clinically healthy WAD goats were assessed in Iwo, Osun State, a region characterized by high ambient temperature and humidity that predispose animals to thermal strain. Physiological indicators of heat stress rectal temperature (RT), respiration rate (RR), and heart rate (HR) were measured across goats with varying coat color patterns. Concurrently, meteorological parameters including ambient temperature and relative humidity were recorded to compute the Temperature Humidity Index (THI). The THI values (79.46–90.99) confirmed that all goats were exposed to moderate to severe heat stress during the study period. Significant differences (p < 0.05) were observed in physiological responses among coat color categories. Goats with darker coat patterns, particularly black and black-mixed colors, exhibited higher RT, RR, and HR compared to lighter-colored counterparts, indicating reduced thermotolerance. Additionally, male goats showed higher respiration rates than females, suggesting sex-related variation in heat adaptation. The findings demonstrate that coat color pattern plays a crucial role in heat stress susceptibility, with darker-coated WAD goats being more vulnerable to thermal load. Therefore, lighter-colored coat patterns may serve as a more suitable selection criterion for breeding programs aimed at improving heat resilience in hot and humid environments of South-Western Nigeria.

Nomenclature and units

k	Kurtosis
γ	Skewness
τ_{MED}	Mean Excess Delay
τ_{RDS}	Root Mean Squared Delay Spread
μ	Mean

1.0 Introduction

At least 1.3 billion people worldwide rely on livestock for their livelihoods and incomes, making it one of the major global sectors that accounts for almost 40% of agriculture GDP (FAO, 2021). But climate changes and the sustainability of goats' production systems is increasingly being impacted by the dangers posed by global warming (Gaughan et al., 2019). According to Tella et al. (2024), stress is defined as the body's response to stimuli that upset homeostasis and frequently have negative consequences. It causes a variety of negative effects, from discomfort to the animal's demise (Arenas et al., 2023). According to Silanikove & Koluman (2015), the three most significant environmental stressors observed in animals are sunlight, high ambient temperatures, and humidity. The most significant environmental stressors noted in animals are solar radiation, high ambient temperatures, and humidity (Martins et al., 2020). Today, there is unmistakable evidence that heat stress is one of the most significant stressors affecting domestic animals, particularly in the world's hotter regions. Heat stress can significantly impact animal welfare, as well as the productivity and productivity performances of animals in tropical and sub-tropical regions (Alam et al., 2021).

Animals' heart rates, metabolic rates, and other critical parameters are influenced by temperature. High ambient humidity combined with heat stress exacerbates the effects of high temperatures (Sejian et al., 2018). Goats are valued by farmers all around the world because of their many functions, including milk production, adaptability in marginal areas, and heat tolerance. Women and children can both have goats because they are not necessary. It appears to be the only animal that may be used effectively in the many socioeconomic contexts found in developing nations. They thrive in unfavorable weather conditions because of their small size and low body mass, low metabolic needs, effective use of high-fiber feed, capacity to lower metabolism, and water-use efficiency (Silanikove & Koluman, 2015). However, according to Alam et al. (2021), one of the main factors that adversely affects goat performance is the temperature environment. According to Alam et al. (2021), the two most significant indicators of heat stress in goats are elevated body temperature and respiration rate. In addition to causing hyperthermia, excessive heat stress may have a number of negative physiological impacts on reproductive processes. Additionally, it can cause enzymatic dysfunction, raise oxidative stress, and lower the quality of meat. Economic losses in the livestock industry as a result of a higher incidence of animal death and a lower rate of animal performance (Hassan et al. 2022).
A goat's physiological profile can be greatly influenced by breed, sex, age, and season, with the former typically increasing or decreasing physiological variables (Abioja et al., 2020). Investigating qualitative features as possible indicators of genetic superiority or production adaptation is important in addition to breed differences. In addition to coat color and type, these qualitative characteristics also include the presence or lack of wattle, horn, beard, and supernumerary teats. The colors of goat coats included red, brown, black, and white, as well as different ratios of these hues. Goats' coat color inheritance is influenced by alleles at three loci (A, B, and S), with genes on the extension locus functioning as modifier genes (El-Sherbiny et al., 2023).
A highly heritable and repeatable characteristic is coat color. Since indigenous Nigerian (WAD) goats are the most common breeds in the humid tropics of Nigeria, where high relative humidity intensifies the effects of high temperatures, it is necessary to ascertain which coat colors of these goats are genetically superior in terms of heat stress. In this study, the effects of sex and WAD coat color patterns on physiological factors associated with heat stress tolerance in native goats were investigated.

2.0 Materials and Methods

In this section, the materials and methods for this research are presented. Data from the animals were collected from various farm locations in Osun State, Nigeria. The laboratory analysis was conducted at the Bio-safety Research Laboratory of the Federal University Oye Ekiti, Ekiti State, Nigeria.

2.1 Environmental Conditions

Iwo is characterized by a tropical wet-and-dry (savanna) climate (Köppen Aw), with an elevation of approximately zero metres above sea level. This low-lying tropical environment exposes livestock to high temperatures and humidity for most of the year. The area records an average annual temperature of 29.66 °C, slightly higher than the national mean for Nigeria, indicating a consistently warm thermal environment. In addition, Iwo experiences approximately 248.57 wet days per year, with about 68% of the year marked by rainfall and high atmospheric moisture. The mean annual precipitation of 133.63 mm contributes significantly to elevated humidity levels during much of the year.

These climatic conditions collectively create an environment highly conducive to heat stress in goats. The combination of high ambient temperature and persistent humidity limits the effectiveness of evaporative cooling, the primary thermoregulatory mechanism in small ruminants. In humid environments such as Iwo, goats particularly those with dark coat colors that absorb more solar radiation are unable to dissipate heat efficiently, resulting in elevated rectal temperature, respiration rate, and heart rate. This prolonged exposure to thermal load may compromise feed intake, metabolic efficiency, immune function, and overall productivity of West African Dwarf goats.
Thus, the environmental profile of Iwo intensifies heat stress risk and strongly influences the physiological responses observed among goats in the study area, highlighting the importance of evaluating coat color patterns and adaptive traits for sustainable management in South-Western Nigeria.

2.2 Experimental animals

Thirty animals (West African Dwarf) were trialed in this study. This comprises thirty West African Dwarf breeds of goats of different colours ranging from black to brown which are principally found in the South-West regions of Nigeria, respectively.

2.3 Experimental animals and their management

The study concentrated on West African Dwarf (WAD) goat breeds that appeared to be in good health. In the agro-ecological zone, this breed is typically raised under intensive husbandry, where the animals are frequently fed on trash heaps and occasionally given corn shafts, cassava peels, kitchen scraps, and crop wastes. To reduce or minimize the conflict or fight between humans and goats for food, the people in this village have changed and revamped this parenting method. Animals were not adequately documented. In general, ethno-veterinary medicine was practiced widely.

2.4 Measurement of meteorological variables

Relative humidity and Atmospheric temperature prevailing during the study were measured using digital hygrometer.

2.5 Measurement of physiological parameters in Nigeria indigenous goats

The 30 West African Dwarf (WAD) goats were sampled in Iwo, Osun State. Three physiological variables include: respiratory rate (RR), pulse rate (PR) and rectal temperature (RT). Each of the animals selected for measurement was restrained and calmed before measurements were taken on them to ensure that they were not unnecessarily stressed. The temperature was taken using digital infrared thermometer (OMRON MC-246, (accuracy, 0.1EC) Omoron Healthcare Com Limited, Kyoto, Japan). The thermometer was inserted about 3cm inside the rectum for the measurements of rectal temperature. Rectal temperatures, respiration rate and heart rate of the sampled goats were recorded as physiological measures/criteria of heat stress according to sex and their coat colour. The physiological responses in each sex and coat colour were recorded three times over 10-12 days. The RR was determined by counting the number of inhalations and exhalations within 60 sec and measuring the heartbeat per minute with a stethoscope. Based on respiratory rate (RR) and heart rate, phenotyping for heat stress susceptibility was carried out (HR). Individuals with RR 50 and HR 130 were identified as heat stress susceptible (HSS) phenotypes, whereas those with RR 30 and HR 100 were identified as heat stress tolerant (HST) individuals in adult goats on the distribution of RR and HR among sex and coat colour in the population.

2.6 Data analysis

Data collected from the physiological parameter measurements were analyzed using the SAS package.

The SAS (2003) program was used to analyze the data. The linear model that was employed is as follows:

$Y_{ij} = \mu + {}_{+}A_i + E_{ij}$

Where Y_{ij} = Single observation.

μ = Overall mean (constant).

A_i = Fixed effect of sex and coat colour patterns (sex and goat coat colour)

E_{ij} = Random residual error

Duncan multiple range test was used to separate the means.

3.0 Results and Discussion

In this section, THI varied from 79.46 to 90.99, indicating that the animals were under stress during the experiment period (Table 4.1).

Table 1 Environmental Conditions Prevailing During The Study

Parameters	Range
Atmospheric Temperature 0ºC	29.30 - 37.50
Relative Humidity %	38.00 - 77.00
Temperature Humidity Index (THI)	79.46 - 90.99

Table 2 shows the physiological indices of WAD goats with varying colours. There were significant ($p<0.05$) differences in all the physiological parameters examined.WAD goats with brown/w had the highest mean value while brown/blk goats had the lowest mean value for rectal temperature. Similar trend was followed in pulse and respiration rate, where goat with black/wh had the highest and goats with brown colour had the least respectively.

Table 2: Effect Of Coat Colour On Physiology Of Wad Goat

Physiological Variable	Black/white	Brown	Brown/white	Brown/black	Black	Overall	P value
Rectal Temperature	39.68±0.56[b]	39.50±0.56[b]	39.90±0.57[a]	39.30±0.55[c]	39.42±0.55[a]	39.56	0.02
Pulse Rate	70.40±1.25[a]	59.11 ±1.05[c]	63.20 ±1.30[b]	63.20±1.30[b]	56.80±1.26[c]	65.10	0.03
Respiration Rate	69.20 ±0.95 [a]	56.44 ±0.89[c]	64.00±0.93[b]	56.80±0.89[c]	66.60±0.54[a]	62.60	0.04

[ab]Means with different superscripts in the same column are significantly different (P<0.05)

Table 3 shows the effect of sex on physiology of WAD goats. The result indicates significant (p<0.05) difference only in respiration rate with male WAD goats having the highest mean value.

Table 3: Effects Of Sex On Physiology Of Wad Goats

Physiological variable	**Male**	**Female**	**Overall**	**P Value**
Rectal Temperature	39.48	39.48	39.48	0.56
Pulse Rate	60.00	61.76	60.88	0.52
Respiration Rate	77.60±2.15[a]	65.20±2.03[b]	71.40	0.03

[ab]Means with different superscripts in the same column are significantly different (P<0.05)

The current study discovered that coat colour has a considerable impact on physiological parameters. This was in line with the fact that coat colouration is a qualitative trait and has a role in heat tolerance (Martin *et al.*,2020). Long-haired goats are better at withstanding radiant heat than short-haired goats, and white or light brown goats are better than brown or black goats (Arenas et al., 2023). Oke et al.,(2022) found that black coat goats had a higher mean value of heat stress index than white, brown, and grey coat goats. This could be as a result of the dark pigmentation absorbing sun radiation, causing the animals to become thermally stressed. Adedeji et al. (2011) also discovered that, perhaps as a result of the high heat absorbance rate of coat pigmentation, coat pigmentation was a crucial determinant of blood characteristics in hot conditions.

Table 3 displays the WAD heat tolerance parameters. Only the respiration rate differs significantly (p<0.05), with male WAD goats showing the highest mean value. The results of Tella et al., (2024) on WAD were consistent with the considerable effect of sex on respiration rate, which showed that male goats had 77.60 beats per minute more than their female counterparts. In this investigation, the only significant influence of sex was on respiratory rate, which was consistent with findings from studies by Oladimeji et al. (2017), and Baenyi (2020) in sheep of different breeds. The respiratory rate was higher in male goats, which was in line with the findings of Oladimeji et al. (2017).

They found that all physiological parameters, including respiratory rate, were higher in male sheep than in female sheep. The fact that male goats pant more aggressively when they see strangers may have something to do with the fact that males have a higher respiratory value than females. It is quite likely that this had an impact on the outcomes. Nonetheless, a number of studies (Oke et al., 2022) have shown that physiological processes (oestrus, gestation, etc.) cause healthy female goats to always breathe more quickly, even under normal circumstances. It was anticipated that female goats would have greater values for these physiological markers because they were possibly pregnant and in the midst of oestrus (Hassan et al., 2022).

Regarding the effect of relative humidity, goats' respiratory frequencies increased even more when a load of high relative humidity was placed on top of an already high ambient temperature. A rise in body temperature was associated with this (Marai et al, 1997). The pulse rates of the goats exposed to heat were higher than those of the others. The main indicators of circulatory homeostasis and overall metabolic health are the pulse rate (Silanikove & Koluman, 2015). These animals have adapted to tropical climates, as evidenced by the activation of their respiratory and heart rates throughout the day shifts to maintain their rectal temperature within the ranges considered typical for this species. This study supported earlier findings by McManus et al., (2022), Baenyi (2020), and El-Sherbiny et al., (2023) that coat pigmentation genes significantly influenced heart rate, respiration rate, rectal temperature, and the heat stress index. Goats seem to absorb sunlight differently due to differences in all physiological markers.

5.0 Conclusions

The study found that compared to other color/coat goats, black and related color/coat goats had higher mean values of physiological characteristics. The animals may experience heat stress as a result of the dark coloration absorbing solar energy. Therefore, it is not advised to breed WADs with black coats or their equivalent, particularly when under heat stress.

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Declaration of conflict of interest

The authors have collectively contributed to the conceptualization, design, and execution of this journal. They have worked on drafting and critically revising the article to include significant intellectual content. This manuscript has not been previously submitted or reviewed by any other journal or publishing platform. Additionally, the authors do not have any affiliation with any organization that has a direct or indirect financial stake in the subject matter discussed in this manuscript.

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