The Relationship Between Coat Colour and Thermotolerance in Tropical Breeds of Sheep and Goats in Maiduguri, Nigeria

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Abstract

The escalating temperatures in Nigeria's Sudano-Sahelian zone necessitate identification of morphological traits that enhance livestock resilience to thermal stress. This investigation examined how coat pigmentation influences thermoregulatory capacity in indigenous sheep and goats managed under semi-intensive systems in Maiduguri. One hundred and twenty adult animals comprising equal numbers of sheep and goats were stratified into four pigmentation categories: White, Black, Brown, and Spotted. Physiological assessments were conducted during the hottest diurnal period (1200-1500 hours) throughout the hot-dry season when environmental conditions reached 38.5 ± 1.2°C ambient temperature and 24 ± 5% relative humidity, yielding a Temperature-Humidity Index of 84.7, indicative of severe thermal challenge. Core body temperature and respiratory frequency served as primary thermotolerance metrics. Statistical analysis revealed highly significant associations between coat pigmentation and both physiological indicators across both species (p<0.01). Animals possessing black pigmentation consistently demonstrated elevated core temperatures and respiratory frequencies, whereas white-coated individuals maintained significantly lower values. Specifically, white-coated sheep maintained rectal temperatures at 39.1°C versus 39.8°C in black-coated counterparts, representing a 0.7°C differential. Similarly, respiratory frequency in white-coated goats averaged 48 breaths/min compared to 65 breaths/min in black-coated animals, reflecting a 35% reduction in thermoregulatory effort. Brown and spotted phenotypes exhibited intermediate values, suggesting a proportional relationship between melanin concentration and thermal load. These results provide empirical validation that lighter pigmentation confers substantial thermoregulatory advantages under extreme tropical conditions. Practical applications include prioritizing lighter-coated breeding stock, implementing targeted management interventions for dark-coated animals including enhanced shade provision and modified feeding schedules, and incorporating coat colour as a selection criterion in breed improvement programs to strengthen climate resilience of small ruminant production systems in tropical agroecological zones.

Running title: Coat colour effects on heat tolerance

Keywords: Heat stress, pigmentation, thermal regulation, small ruminants, climate adaptation, Sahel

Introduction

Small ruminant production is a cornerstone of livelihood and food security in Nigeria, particularly in the semi-arid regions like Maiduguri, providing a critical source of meat, income, and socio-cultural capital for millions (Mustapha et al., 2024). However, the productivity of these animals is severely

constrained by environmental stressors, with heat stress being a predominant challenge. The increasing frequency and intensity of heatwaves, exacerbated by climate change, pose a significant threat to sustainable livestock production in tropical regions (Rojas-Downing et al., 2017).

Thermotolerance, defined as the ability of an animal to maintain homeothermy and production under high ambient temperatures, is a complex trait influenced by genetics, physiology, and morphology (McManus et al., 2022). Among the morphological traits, coat colour has been identified as a key factor modulating an animal's thermal balance. The underlying mechanism is rooted in basic physics: dark coats, due to high concentrations of melanin, have a high solar radiation absorptivity, while light coats, with low melanin, have high reflectivity (Silva et al., 2017). Consequently, dark-coated animals are hypothesized to accumulate more radiant heat, increasing their heat load and potentially compromising their thermoregulatory capacity.

Previous studies have provided evidence for this relationship. In West African Dwarf (WAD) goats, Tella et al. (2024) reported that black-coated individuals exhibited significantly higher rectal temperatures and respiratory rates compared to their white or brown counterparts under hot conditions. Similarly, in WAD sheep, Sanusi et al. (2011) found that animals with lighter coat colours demonstrated superior heat tolerance indices. These findings underscore the potential of coat colour as a simple, non-invasive morphological marker for genetic selection towards thermotolerance.

Maiduguri, situated in the Sudano-Sahelian ecological zone of Nigeria, presents a unique and challenging environment characterized by extreme climatic conditions. With ambient temperatures soaring to 41°C during the hot-dry season and high humidity in the rainy season, local sheep and goats are perpetually under thermal stress (Umar & Aliyu, 2020). While the general principle of coat colour's influence is established, localized studies are imperative. Genetic variations, specific breed adaptations, and microclimatic conditions can modulate this relationship, making findings from one region not entirely transferable to another. Therefore, this study was conducted to investigate the relationship between coat colour and key thermotolerance indicators in the local sheep and goat populations of Maiduguri, providing context-specific data to inform farmer selection practices and breeding strategies.

Heat Stress and Its Impact on Small Ruminants
Heat stress occurs when an animal's capacity to dissipate body heat is surpassed by the combined heat load from metabolism and the environment. In small ruminants, this triggers a cascade of physiological and behavioral responses aimed at maintaining thermal homeostasis. Key physiological indicators include an increase in core body temperature (rectal temperature) and a elevated respiratory rate (panting) as primary avenues for evaporative cooling (Marai et al., 2020). Prolonged heat stress depresses feed intake, growth rates, reproductive efficiency, and immune function, leading to substantial economic losses for farmers (McManus et al., 2022). The Temperature-Humidity Index (THI), which integrates ambient temperature and relative humidity, is widely used to quantify the level of heat stress animals experience.

Coat Colour as a Determinant of Thermoregulation
The role of coat colour in thermoregulation is primarily governed by its radiative properties. Melanin, the pigment responsible for dark colouration, is an effective absorber of a broad spectrum of solar radiation. In contrast, white or light-coloured coats reflect a significant portion of the visible and near-infrared radiation (Silva et al., 2017). This differential absorption directly influences the heat load on the animal's skin surface. A study on Brazilian sheep breeds found that animals with white coats had skin temperatures up to 5°C lower than those with black coats under the same solar exposure (Cândido et al., 2020).

Beyond colour, other coat characteristics like hair length and density also play a role, but colour remains a primary and easily identifiable factor. The genetic control of coat colour, involving genes such as the *Melanocortin 1 Receptor (MC1R)*, offers a potential pathway for marker-assisted selection for thermotolerance (Brito et al., 2021). This makes coat colour a practical and heritable trait for farmers to consider in their breeding stock.

Small Ruminant Production in Maiduguri
Maiduguri, the capital of Borno State, lies in a region where livestock farming is a major economic activity. The local breeds of sheep (e.g., Borno White, Uda) and goats (e.g., Sahelian, WAD variants) are prized for their adaptability. However, the climate is increasingly harsh. Umar and Aliyu (2020) documented a clear trend of rising temperatures and erratic rainfall patterns in the region, pushing the existing adaptive capacity of local breeds to their limits. The management system is predominantly semi-intensive, where animals are often exposed to direct sunlight for significant parts of the day, making radiative heat gain a critical issue. Despite this, there is a scarcity of empirical data linking the phenotypic diversity of these local breeds, particularly coat colour, to their resilience in the face of this specific climatic challenge. This study aims to fill this critical knowledge gap.

Methodology
Study Area and Period
The study was conducted at the Kashim Ibrahim University Teaching and Research Farm, Maiduguri (11.50°N, 13.05°E), during the peak of the hot-dry season (March-May), when ambient temperatures consistently exceeded 35°C and relative humidity was low (19-30%).

Animal Management and Selection
A total of 120 adult, clinically healthy animals (60 sheep and 60 goats) of local breeds were randomly selected. The animals were managed under a semi-intensive system, grazing during the cooler morning hours and housed in open-sided pens for the rest of the day. Animals were classified into four coat colour groups based on a standardized chart: White (W), Black (B), Brown (Br), and Spotted/Mixed (S).

Data Collection

Data were collected between 12:00 and 15:00 hours, the period of peak daily heat.

1. Physiological Parameters: Rectal Temperature (RT, °C) was measured using a digital veterinary thermometer. Respiratory Rate (RR, breaths/min) was determined by counting flank movements for 30 seconds and multiplying by two.

2. Environmental Parameters: Ambient temperature (°C) and relative humidity (%) were recorded using a digital thermo-hygrometer to calculate the Temperature-Humidity Index (THI) using the standard formula: $THI = Tdb - (0.55 - 0.55\,RH)(Tdb - 58)$, where Tdb is dry bulb temperature (°F) and RH is relative humidity (decimal form).

Statistical Analysis

Data were analyzed using SPSS version 26. Descriptive statistics (mean ± standard deviation) were computed for all parameters. A one-way Analysis of Variance (ANOVA) was used to compare means of RT and RR across the different coat colour groups, with a post-hoc Tukey's test for mean separation. The level of statistical significance was set at $p < 0.05$.

Results and Discussion

Descriptive Statistics and Environmental Conditions

The mean ambient temperature and relative humidity during the data collection period were 38.5 ± 1.2°C and 24 ± 5%, respectively, resulting in a mean THI of 84.7. A THI above 80 is generally classified as a "severe heat stress" zone for livestock (Marai et al., 2020), confirming that the animals were under significant thermal load during the study. The distribution of coat colours was: White (32.5%), Brown (28.3%), Black (20.8%), and Spotted (18.3%).

Relationship Between Coat Colour and Physiological Indicators

The results demonstrated a clear and statistically significant effect of coat colour on both rectal temperature and respiratory rate in both sheep and goats ($p < 0.01$), thereby confirming our primary hypothesis.

Table 1: Mean (±SD) Rectal Temperature (°C) and Respiratory Rate (breaths/min) by Coat Colour

Species	Parameter	White (W)	Brown (Br)	Black (B)	Spotted (S)	p-value
Sheep	Rectal Temp.	39.1 ± 0.3^a	39.4 ± 0.4^b	39.8 ± 0.3^c	39.5 ± 0.4^b	<0.001
	Resp. Rate	45 ± 6^a	52 ± 7^b	62 ± 8^c	55 ± 7^b	<0.001
Goats	Rectal Temp.	39.0 ± 0.3^a	39.3 ± 0.3^b	39.7 ± 0.4^c	39.4 ± 0.4^b	<0.001
	Resp. Rate	48 ± 5^a	55 ± 6^b	65 ± 7^c	57 ± 6^b	<0.001

Means within a row with different superscripts (a, b, c) are significantly different ($p < 0.05$).

As illustrated in Table 1, animals with black coats consistently exhibited the highest values for both RT and RR, followed by spotted, brown, and white-coated animals. For instance, black-coated sheep had a mean RT of 39.8°C, which was 0.7°C higher than that of white-coated sheep (39.1°C). This difference is not only statistically significant but also physiologically crucial, as a sustained elevation in core body temperature of this magnitude can severely impair metabolic efficiency and protein synthesis (McManus et al., 2022). Similarly, the respiratory rate of black-coated goats (65 breaths/min) was 35% higher than that of white-coated goats (48 breaths/min), indicating a substantially greater effort to dissipate heat through evaporative cooling.

These findings are consistent with the established biophysical principles and previous research. The superior thermotolerance of light-coloured coats is directly attributable to their high albedo, reflecting a larger proportion of incoming solar radiation and thus reducing the heat load on the animal (Silva et al., 2017). The significantly elevated RT and RR in black-coated animals align with the results of Tella et al. (2024) on WAD goats and Sanusi et al. (2011) on WAD sheep. The intermediate values observed in brown and spotted animals suggest a dosage effect, where the proportion of dark hair in the coat correlates with the degree of heat stress. The high respiratory rate in dark-coated animals, while a vital cooling mechanism, represents a metabolic cost in terms of energy and water loss, which can negatively impact overall productivity in the long term (Marai et al., 2020).

In the specific context of Maiduguri, where THI values frequently enter the "severe stress" range, these results have profound implications. The high prevalence of black and dark brown coats in the local population, as observed in this study (over 49% combined), indicates that a significant portion of the small ruminant herd may be operating at a physiological disadvantage for a large part of the year. This directly translates to reduced growth rates, lower fertility, and higher susceptibility to diseases, undermining the resilience and economic viability of smallholder farms.

Conclusion and Recommendations

This study provides compelling, context-specific evidence that coat colour is a significant determinant of thermotolerance in sheep and goats reared in the harsh climatic environment of Maiduguri, Nigeria. The results robustly support the hypothesis that animals with lighter (white) coats exhibit superior thermoregulatory ability, maintaining lower rectal temperatures and respiratory rates under severe heat stress compared to their dark-coated counterparts.

Based on these findings, the following recommendations are proposed:

1. Farmer Education and Selection: Extension services should educate farmers on the economic and animal welfare benefits of selecting for lighter coat colours. Farmers should be encouraged to retain white or light-brown ewes/does as breeding stock and consider using rams/bucks with desirable light-coloured coats.
2. Breeding Program Integration: While maintaining genetic diversity, local and national breeding programs for small ruminants should incorporate coat colour as a secondary selection criterion alongside traits like growth and fecundity, to enhance climate resilience.
3. Management Practices: For existing herds with dark-coated animals, farmers should be advised to provide enhanced management interventions during heat stress periods, such as ensuring adequate shade, access to clean drinking water, and adjusting feeding schedules to cooler times of the day.

In conclusion, leveraging coat colour as a simple, low-cost morphological marker presents a sustainable and practical strategy to enhance the heat resilience and productivity of small ruminants in Maiduguri and other tropical regions facing escalating climatic challenges.

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