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Effects of Coat Colour Pattern on Heat Stress Among West African Dwarf Goat

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ABSTRACT

Background and Objective: West African Dwarf Goats, known for their resilience, are vital to agriculture in these regions. However, heat stress can significantly impact their health, reproduction and productivity. The purpose of this study was to look into the impact of coat color patterns on the physiological, hematological and serum biochemical profiles of West African Dwarf goats exposed to heat stress. **Materials and Methods:** A 100 WAD goats with different coat colors (black, grey, white and brown) were studied. Environmental conditions were recorded to calculate the temperature humidity index (THI). Rectal temperature, respiratory rate, pulse rate, haematological parameters and serum biochemistry were measured. Temperature and humidity index (THI) was calculated at various environmental conditions prevailing during the study and consequent on this, an Analysis of Variance (ANOVA) was performed with respect to the different coat colour patterns of WAD goats to heat stress measured. **Results:** There was a significant ($p<0.05$) variation in the effects of coat color patterns on thermoregulatory, haematological and serum biochemical variables. When compared to goats with other coat color patterns, all the physiological variables investigated with the majority of these blood parameters were impaired in goats with black coat color patterns. Variations in thermoregulatory, hematological and serum biochemical parameters in goats with black coat colour patterns may have an impact on their productive and reproductive performance in high-temperature situations. **Conclusion:** The study discovered that coat colour pattern was a critical driver of blood characteristics in high environmental temperatures, which could be attributed to coat pigmentation's high heat absorbing rate.

KEYWORDS

Coat colour patterns, haematological parameters, heat tolerance, WAD goats, serum biochemical parameter

INTRODUCTION

Livestock is one of the most important sectors in the world, accounting for 40% of agricultural GDP and employing at least 1.3 billion people[1]. Climate change and global warming, on the other hand, are becoming important concerns to the sustainability of animal production systems[2]. Stress is defined as the body's reaction to stimuli that disrupt homeostasis, frequently with negative consequences[3]. It has a

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variety of negative effects, ranging from pain to animal death[4]. The most significant environmental stressors observed in animals are solar radiation, high ambient temperature and humidity[5]. Heat stress is one of the most significant stressors impacting domestic animals today, particularly in hotter regions of the world[6].

Heat stress can have a significant impact on animal welfare and productivity in tropical and subtropical areas[7]. In animals, temperature influences heart rates, metabolic rates and other vital variables. When heat stress is combined with high ambient humidity, the effect of high temperature is exacerbated[8]. Goats are valued by farmers all around the world for their numerous purposes (milk production, adaptability in marginal areas and heat tolerance). The goat is easy to care for and can be managed by both women and children. It is likely the most suitable livestock for effective use in various socioeconomic settings in developing countries. Goats thrive in harsh climates due to their small body size and weight, low metabolic needs, efficiency in utilizing high-fiber forage, ability to reduce metabolism and effective water use[9].

The temperature on the other hand, is a critical element that has a detrimental impact on goat performance[10]. The most prominent symptoms of heat stress in goats are increased respiration rate and body temperature[10]. Excessive heat stress can cause hyperthermia and have a number of physiologically negative consequences on reproductive processes. It can also lower meat quality, raise oxidative stress (which is harmful) and cause enzymatic malfunction[11]. Heat stress leads to various alterations in biological functions, such as reduced feed intake and disruptions in water, protein, energy and mineral balances. It also affects enzymatic reactions, hormonal secretions and blood metabolism[12].

According to Daramola *et al.*[13] and Daramola *et al.*[14], economic losses in the livestock sector stem from increasing rates of animal mortality and decreasing rates of animal performance. Breed, sex, age and seasons can all have a significant impact on a goat's haematological profile, with season traditionally boosting or lowering haematological factors[15,16]. Aside from breed differences, it is necessary to investigate qualitative traits as potential markers of genetic superiority or production adaptation. These qualitative characteristics include coat type and color, as well as the presence or absence of wattle, horn, beard and supernumerary teats. Goat coat colors ranged from black, brown and red to white and combinations of these colors in various proportions. Alleles in three loci (A, B and S) influence coat color inheritance in goats, with genes on the extension locus acting as modifier genes[17]. Coat color is a highly reproducible and heritable trait[18]. There is a need to determine the genetic superiority of different coat colors of indigenous Nigerian (WAD) goats in terms of heat stress because these are the predominant goats in Nigeria's humid tropics, where high relative humidity exacerbates the effects of high temperature. The goals of this study were to see how coat color patterns affected physiological, hematological and serum biochemical markers related to heat stress tolerance in indigenous goats.

MATERIALS AND METHODS

Study area: Data and samples from the animals were collected from various farms in Osun, Oyo and Kwara States, Nigeria from August, 2018 to February, 2019. The study was carried out from January, 2020 to March, 2020. The agro-ecosystems of Osun, Oyo and Kwara States in Nigeria are characterized by diverse climates and agricultural practices. Osun State, located in Southwestern Nigeria, experiences a tropical rainforest climate. The annual mean rainfall is approximately 1,200 to 1,400 mm. The region has two distinct wet seasons: The main rainy season occurs from April to July, while a shorter, less intense rainy period occurs from September to November. The annual mean temperature in Osun State ranges between 24 and 28°C. The hottest months are typically February and March, while the cooler months are December and January. Temperatures tend to be relatively stable due to the tropical climate, with slight variations influenced by the rainy and dry seasons. Osun State is predominantly covered by tropical rainforest vegetation, characterized by dense forests with a rich diversity of plant species.

Oyo State, located in Southwestern Nigeria, has a tropical savanna climate with distinct wet and dry seasons. The annual mean rainfall in Oyo State ranges from approximately 1,200 to 1,500 mm. The rainy season typically spans from April to October, with a peak in rainfall occurring between June and September. The annual mean temperature in Oyo State is between 25 and 29°C. The vegetation in Oyo State is characterized by a mix of tropical rainforest and guinea savanna.

Kwara State, situated in the North-Central Region of Nigeria, experiences a tropical wet and dry climate. The annual mean rainfall in Kwara State ranges from approximately 1,000 to 1,500 mm. The rainy season typically extends from April to October, with the peak rainfall occurring between June and September. The annual mean temperature in Kwara State is between 25 and 30°C. The vegetation in Kwara State is primarily characterized by guinea savanna, also known as tropical savanna. These states collectively enhance Nigeria's agricultural productivity, utilizing both rain-fed and irrigation farming systems to maximize yield and support local economies. The laboratory analysis was carried out at the Federal University of Technology's Bio-safety Research Laboratory in Akure, Ondo State.

Experimental animals: In this investigation, 100 experimental animals were employed. West African Dwarf goats sampled in Nigeria's South West.

Experimental animals, site and their management: Data and samples from the animals were collected from 100 WAD goats based on their coat colour patterns in the late dry season (January-March). The laboratory analysis was carried out at the Federal University of Technology's Bio-safety Research Laboratory in Akure, Ondo State, Nigeria.

This study focused on goats of the West African Dwarf (WAD) that appeared to be healthy. These goats are often stock raised in the agriculture ecological zone under substantial or semi-intensive husbandry, with the animals given cassava peels, corn shafts, household rubbish, agricultural leftovers and most commonly, garbage piles. These communities' citizens have embraced this method of goat rearing to reduce food conflict between humans and goats. The records for the animals were not preserved properly. At the time, ethno-veterinary medicine was a popular practice.

Thermoregulatory analysis:

Rectal temperature: This was taken on each animal using a digital thermometer (Shanghai Ningbo company, Baihe Town, State of Shanghai in China). The sensory tip was disinfected and inserted into the rectum at the display of L°C by the thermometer (which indicated that the thermometer was used for temperature reading). This was removed after the sound of the alarm signal. The displayed body temperature was then recorded.

Respiratory rate: This was determined by counting the number of flank movements per minute.

Heart beat rate: This was determined for each animal by placing the fingertips on the femoral arteries of the hind limb for 1 min.

Haematological analysis: Blood was drawn from the jugular veins of each goat. The 100 blood samples of each animal experimented were held in two 5 mL vacuum tubes. For hematological studies (anti-coagulant), 1 of the 5 mL blood tubes contains ethylene diamine tetra-acetic acid. Packet cell volume (PCV %), hemoglobin (Hb g/dL), red blood cell (RBC$\times 10^6$/L) and white blood cell (WBC$\times 10^4$/L) were assessed by Daramola *et al.*[14].

Serum biochemical analysis: Serum was extracted from the second 5 mL vacuum set of blood tubes, centrifuged for 20 min at 3500 rpm and stored at -200ºC. Gaughan *et al.*[18] approach was used to determine total plasma proteins (TP×g/dL) and albumin concentration (Al×g/dL). Total serum globulin concentration was calculated using the difference between total serum proteins and serum albumin (Gl×g/dL). Glucose (Glu×mg/dL), sodium (Na^+×mmol/L), potassium (K^+×mmol/L) and calcium (Ca^{2+}×mmol/L) were determined using this approach.

Data analysis: The SAS program version 9.21 was used to analyze the data. The linear model that was employed is as follows[2]:

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

Where:

Y_{ij} = Single observation
μ = Overall mean (constant)
A_i = Fixed effect of coat colour patterns (WAD goats)
E_{ij} = Random residual error

Duncan's multiple range test was used to separate the means.

Ethical consideration: In conducting research effects of coat colour pattern on heat stress among West African Dwarf goat, all procedures involving animals have been conducted with the utmost respect for their welfare, in compliance with national and international guidelines for the ethical treatment of animals in research.

RESULTS

Environmental conditions prevailing during the study: Table 1 shows the environmental conditions that prevailed during the experimental period. The ambient temperature ranged from 25-36°C with an average of 31.44±0.10°C. The relative humidity ranged from 76.16-89.5% with an average of 83.93±0.11%. The temperature humidity index (THI) during the experimental period ranged from 74.44-94.54 with an average of 86.26±0.32.

Table 2 shows the variation in physiological parameters with coat colour patterns of WAD goats. The results revealed that WAD goats with black coat colour patterns had the highest values of all the physiological parameters investigated followed by grey, brown and WAD goats with white coat colour patterns had the lowest values.

Effects of breed and coat colour on haematological and serum biochemistry of WAD goats: Table 3 and 4 show the least squares means of packed cell volume (PCV), haemoglobin (Hb g/dL), red blood cell counts (RBC×10^6/μL), white blood cell counts (WBC×10^3/μL), serum biochemistry which includes total protein (Tp×g/dL), albumin (AL×g/dL), globulin (GL×g/dL), albumin and globulin ratio (AL/GL%), glucose (GUL×mg/dL), sodium (Na^+×mmol/L), potassium (K^+×mmol/L) and calcium (Ca^{2+}×mmol/L), concentrations in WAD goats of different coat colours. The results showed that there was a significant ($p<0.05$) difference in the effects of coat colour pattern on blood parameters except for albumen and globulin ratio ($p>0.05$).

Table 1: Environmental conditions prevailing during the trial

Parameter	Range	Mean±SEM
Environmental conditions		
Ambient temperature (°C)	25-36	31.44±0.10
Relative humidity (%)	76.16-89.5	83.93±0.11
Temperature humidity index (THI)	74.44-94.54	86.26±0.32

SEM: Standard error of mean

Table 2: Variation in physiological parameters with coat colour patterns of WAD goats

	Parameter			
Coat color patterns	White	Grey	Black	Brown
Heart beat rate (HR) (bpm)	81.56±2.48^{b}	91.17±3.32^{a}	95.40±3.07^{b}	81.22±2.89^{b}
Respiration rate (RR) (bpm)	61.07±2.69^{b}	63.27±3.46^{a}	71.91±3.16^{b}	65.30±3.27^{b}
Rectal temperature (RT) (°C)	39.10±0.11^{b}	39.61±0.15^{a}	40.98±0.16^{a}	39.30±0.09^{a}

Means on the same row with different superscripts is significantly ($p \leq 0.05$) different and SEM: Standard error of mean

Table 3: Effects of coat colour patterns on haematological parameters of WAD goats

	Colour	PCV	HB	RBC	WBC	N
WAD	Black	33.08±0.39^{a}	9.39±0.23^{a}	11.28±0.48^{a}	5.21±0.24^{b}	20
WAD	Grey	30.52±0.62^{b}	8.58±0.36^{ab}	10.50±0.38^{ab}	6.32±0.38^{a}	12
WAD	White	25.34±0.79^{c}	7.45±0.46^{b}	10.28±0.48^{b}	6.26±0.48^{a}	5
WAD	Brown	28.21±0.79^{a}	8.55±0.46^{ab}	10.09±0.48^{b}	5.74±0.48^{b}	8

Means with different superscripts among colours are statistically significant ($p<0.05$), WAD: West African Dwarf goat, N: Number of sample, PCV: Packed cell volume, HB: Haemoglobin, RBC: Red blood cell, WBC: White blood cell BLK and BRW: Brown

Table 4: Effect of breed and coat colour patterns on serum biochemical parameters of WAD goats

Colour	TP	ALB	GLOB	AGR	GLU	Na^{+}	K^{+}	Ca^{2+}	N
Black	4.88±0.11^{a}	3.36±0.10^{a}	1.42±0.04^{ab}	2.41±0.11^{a}	79.55±0.93^{a}	97.24±1.23^{a}	6.09±0.10^{a}	8.90±0.17^{c}	20
Grey	4.27±0.17^{a}	2.88±0.15^{ab}	1.38±0.07^{abc}	2.18±0.18^{a}	73.60±1.47^{a}	92.16±1.95^{a}	5.19±0.16^{a}	10.55±0.27^{ab}	12
White	4.92±0.22^{a}	3.19±0.20^{ab}	1.7±0.09^{a}	1.90±0.23^{a}	68.98±1.87^{a}	91.14±2.47^{a}	4.54±0.20^{a}	11.72±0.34^{a}	5
Brown	4.73±0.22^{a}	3.31±0.20^{bc}	1.22^{bc}±0.09^{bc}	2.43±0.23^{a}	69.24±1.87^{a}	92.77±2.47^{a}	5.00±0.20^{a}	11.76±0.34^{bc}	8

Means with no superscripts among colors and between breeds are statistically similar ($p>0.05$), WAD: West Africa Dwarf goat, N: Number of the animal, TP: Total protein, ALB: Albumin, GLOB: globulin, AGR: Albumin to globulin ratio, GLU: glucose, Na^{+}: Sodium ion, K^{+}: Potassium ion, Ca^{2+}: Calcium ion

DISCUSSION

Table 1 shows the environmental conditions that prevailed during the experimental period. The ambient temperature ranged from 25-36°C with an average of 31.44±0.10°C. The relative humidity ranged from 76.16-89.5% with an average of 83.93±0.11%. The temperature humidity index (THI) during the experimental period ranged from 74.44-94.54 with an average of 86.26±0.32. The results revealed that WAD goats with black coat colour patterns had the highest values of all the physiological parameters investigated followed by grey, brown and WAD goats with white coat colour patterns had the lowest values. They show the least squares means of packed cell volume (PCV), haemoglobin (Hb g/dL), red blood cell counts ($RBC \times 10^{6}/\mu L$), white blood cell counts ($WBC \times 10^{3}/\mu L$), serum biochemistry which includes total protein (TP×g/dL), albumin (AL×g/dL), globulin (GL×g/dL), albumin and globulin ratio (AL/GL%), glucose (GUL×mg/dL), sodium (Na^{+}×mmol/L), potassium (K^{+}×mmol/L) and calcium (Ca^{2+}×mmol/L), concentrations in RS and WAD goats of different coat colors. The result showed that there was a significant ($p<0.05$) difference in the effects of coat colour pattern on blood parameters except for albumen and globulin ratio ($p>0.05$).

The observed ambient temperature in this study was higher than the critical temperature of 24 to 27°C for most species as indicated by Sejian *et al*[19]. Relative humidity values obtained in this study were higher than the reported range of values (9.20 to 33.93%) by Al-haidary *et al.*[4]. Temperature-humidity index values of 86.26 mean value were recorded for this study[20]. The temperature humidity index of 74 or less is considered normal, 75 to 78 is alert status, 79 to 83 is danger status and a temperature-humidity index equal to or above 84 is an emergency as reported by Helal *et al.*[21]. In this present study, the temperature-humidity index was higher than 84 during the experimental period and classified as severe heat stress. Thus, the obtained climatic data revealed that goats exposed to solar radiation in the late dry season during this experimental period were extremely heat stressed.

The extent of radiant heat absorbed by an animal's coat is influenced by factors such as the color, length and condition of its hair[2]. Physiological indicators like rectal temperature and pulse rate are often used to assess an animal's adaptability to heat stress[21]. These indicators were found to be higher at midday compared to morning and afternoon, which aligns with expectations due to the higher ambient temperatures at midday[21,22]. Nevertheless, the rectal temperatures recorded in this study remained within the normal reference range (38-41°C) for tropical goats[23]. In contrast, lighter coat colors such as white, grey and brown help facilitate radiant heat loss, which can influence body weight and other productivity-related adaptability factors in livestock species[24]. Rectal temperature is widely regarded as a crucial measure of physiological status and a reliable indicator of stress in animals[25]. Even a rise of less than 1°C in rectal temperature, as observed in this study, can significantly reduce performance in most livestock species[26]. The highest rectal temperatures and pulse rates were observed in black-coated goats, followed by those with grey and brown coats. These findings were consistent with those of Okourwa[27], suggesting that the elevated rectal temperatures in black goats are a result of increased absorption of solar radiation by their darker pigmentation. Okourwa[27] also reported an increase in pulse rate associated with coat color in sheep, with black-coated sheep having a higher pulse rate (87.49 beats/min) compared to those with light brown coats (79.00 beats/min). This increase in pulse rate may be attributed to vasodilation in the skin's capillary beds, leading to increased blood flow to the body's surface to aid in heat dissipation[28]. The elevated pulse rate in black-coated goats is likely due to the higher rectal temperature associated with their darker coats, which may exceed the comfort zone, thereby causing blood to be redistributed to peripheral tissues during heat exposure[4].

The observed result with the respiratory rate was significantly ($p<0.05$) affected by coat colour pattern. It followed the same trend observed with rectal temperature. White coat color pattern had the lowest value of 61.07±0.06 breaths/min while black had the highest value of 71.91±0.16 breaths/min. Black animals had the highest respiratory rate. The animals are painted to increase body cooling by respiratory evaporation since the major evaporatory heat loss mechanism is panting.

According to the findings of the current study, coat color has a significant impact on haematological indicators. This was consistent with the idea that coat coloration is a qualitative characteristic that contributes to heat tolerance[29]. However, hematological parameters appear to be most harmed in black coat colors in this investigation. According to Ribeiro *et al.*[30], animals adjust hematological parameters to maintain a steady body temperature. Black coat type had the greatest red blood cell count due to black animal's high heat burden. The quantity of red blood cells in black sheep rose as a result of heat stress. This may be due to the physiological need for increased hemoglobin to support oxygen circulation during panting in animals experiencing heat stress. The rise in red blood cell count in response to heat stress aligned with the findings of Li *et al.*[11] who also observed an increase in red blood cell numbers under heat stress conditions. Additionally, white blood cell (WBC) count was significantly ($p<0.01$) affected by coat color, with black-coated animals showing the lowest WBC values. The average WBC count for animals with a black coat and extensive white markings was notably lower than that for animals with a red coat and extensive white markings (6.32±0.38, 7.42±0.48 and 10.35±0.34 no/mm, respectively). Heat stress tends to reduce white blood cell counts in animals, which was consistent with the findings of Li *et al.*[11], who reported a similar reduction in white blood cell counts in mice under heat stress. Adedeji[3] also found that black goats had lower white blood cell counts compared to brown goats with white markings. However, Sanusi *et al.*[31] observed no effect of coat color genotype on white blood cell counts in crossbred pigs.

When Red Sokoto goats were compared to West African Dwarf goats of the same color, there was a significant difference in the mean value of white blood cell count of red/W marks. The color of the coat also had a significant ($p<0.01$) effect on plasma sodium concentration (Na^{2+}). The average Na value ranged from 77.85±1.53 to 97.16±1.95 mmol/L. The value of br/w was the lowest, while the value of black/w was the highest. The mean values for black/W marks and red/W markings did not differ significantly. The coat color also had a significant ($p<0.01$) effect on plasma potassium levels. The mean value ranged from 3.76±0.12 to 5.19±0.16 mmol/L, with the black/W coat-coloured goats having the greatest value and the red/W coat-coloured goats having the lowest value. Animals with dark pigmentation appeared to have reduced sodium and potassium concentrations as a result of high net solar radiation impinging on their skin. Heat stress lowered the concentrations of sodium and potassium. The decrease in plasma electrolytes, particularly cations, with increasing body temperature, was consistent with the findings of Silanikove[32], but contradicted the findings of Silanikove[33], who found that heat stress increased plasma potassium in Holstein and Jersey cows but decreased it in Australian milking zebu. According to the findings of the current study, coat color has a significant impact on hematological indicators. This was consistent with the idea that coat coloration is a qualitative characteristic that contributes to heat tolerance[34,35]. Long-haired goats tolerate radiant heat better than short-haired goats and white or light brown goats tolerate it better than brown or black goats[2]. Adedeji[3] discovered that black coat goats had a higher mean heat stress index value than white, brown or grey coat goats. This could be due to the dark pigmentation absorbing sun radiation and generating heat discomfort in the animals. Adedeji[3] discovered that coat pigmentation was an important driver of blood characteristics in high-temperature situations, presumably due to the high heat-absorbing rate of coat pigmentation. The current investigation found that glucose and albumin levels were usually high in goats with black coat patterns. These findings contradicted those of Okourwa[27], who discovered black and light brown West African Dwarf male sheep in Southern Nigeria. Serum biochemical characteristics contribute to serum viscosity, normal blood pressure and animal physiological states. They are also vital in maintaining the osmotic pressure between the circulating fluid and the fluid in the tissue, which allows for the flow of materials between the blood and the cells[26]. The general high albumin values reported in goats with black coat color could be attributed to the experimental area's grazing system, implying the likelihood of feed intake[36,37].

The study examines the effects of coat color pattern on heat stress among West African Dwarf goats has significant implications for animal welfare, breed selection and climate adaptation. By understanding how coat color influences heat stress responses, livestock managers can enhance the welfare of these goats, particularly in regions with high temperatures. Furthermore, the findings help inform breeding programs, encouraging the selection of goats with coat colors that offer better heat tolerance. This understanding is especially crucial in the context of climate change, as it help develop strategies for the sustainable adaptation of livestock.

The applications of this research are diverse. Livestock managers can utilize coat color as an indicator of heat stress risk, allowing for more informed decisions regarding housing and husbandry practices. Geneticists and breeders can incorporate coat color patterns into their selection criteria, potentially improving the resilience of goat populations. Additionally, agricultural policymakers can leverage these findings to formulate guidelines that prioritize heat stress mitigation in livestock management, particularly in vulnerable regions.

To maximize the benefits of this research, several recommendations were made. First, further longitudinal studies should be conducted to explore the long-term effects of coat color patterns on health and productivity under various environmental conditions. Additionally, it is essential to provide farmers with education and training on recognizing the symptoms of heat stress and understanding the implications of coat color for their livestock's well-being. Lastly, an integrated approach that combines genetic, environmental and management factors should be encouraged in breeding strategies to enhance overall resilience against heat stress.

However, the study is not without limitations. One notable constraint is the potential lack of diversity in coat color patterns which may affect the generalizability of the findings. Moreover, other environmental factors, such as humidity and housing conditions, may not have been fully controlled or accounted for, potentially influencing heat stress responses. If the study only examines short-term effects, it may overlook long-term adaptations or changes in heat stress responses due to factors like age or acclimatization. Overall, the research sheds light on an important aspect of goat husbandry, providing valuable insights for improving animal welfare and resilience in the face of increasing heat stress challenges.

CONCLUSION

The study discovered that coat colour pattern was a critical driver of blood characteristics in high environmental temperatures, which could be attributed to coat pigmentation's high heat absorbing rate. It was also observed that WAD goats with black coat colour patterns were more susceptible to heat stress than other coat colour patterns goats. Understanding the hematological and serum biochemistry features of goats will go a long way toward enhancing the genetic background of the indigenous herd.

SIGNIFICANCE STATEMENT

The study on Coat Colour Pattern's impact on Heat Stress in West African Dwarf Goats is crucial for animal husbandry in tropical climates. Understanding how coat colors affect thermoregulation can guide breeding and management strategies, improving goat welfare and productivity. This research offers insights into how different coat colors influence growth, reproduction and health. Identifying heat-resistant coat patterns allows farmers to enhance herd resilience and efficiency, contributing to food security and economic stability in regions where these goats are vital.

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