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Regression Analysis of Physiological Responses of Red Sokoto and West African Dwarf Goats to Heat Stress

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ABSTRACT
Background and Objective: Livestock goes through diverse forms of stress, including psychological, chemical, nutritional, thermal and physical stress. Changes in rectal temperature, respiratory rate, heart rate and skin temperature are in part physiological responses to thermal stress. This study was conducted to identify the regression analysis of physiological responses of ancient/native breeds of goats (West African Dwarf and Red Sokoto) to heat stress in Nigeria. **Materials and Methods:** Physiological data (rectal temperature pulse rate and respiration rate) at various environmental conditions (ambient temperatures and humidity) were taken from 400 experimental animals (200 West African Dwarf breeds and 200 red Sokoto breeds of goats in Osun, Oyo and Kwara states, Nigeria. Temperature and humidity index (THI) were 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 physiological indices that were measured. **Results:** Regression analysis between the parameters was also carried out, generating the coefficient of determination (R^2) to indicate the efficiency of prediction. The results from the physiological parameter measurements and THI analysis revealed that the results for the physiological parameters were similar at breed level; heart beat rate, rectal temperature and respiration rates changed significantly with increasing THI values. The regression analysis showed that THI had a positive and significant ($P<0.05$) effect on heat beat rate R^2 (0.623), respiration rate R^2 (0.36) and rectal temperature R^2 (0.157) of Red Sokoto Breed. The THI also had positive and significant ($P<0.05$) in West African Dwarf goats for all physiological parameters. Heart beat rate R (0.544) respiration rate R^2 (0.359) and rectal temperature R^2 (0.187). **Conclusion:** These physiological responses make goats exist and linger in harsh and cacophonous environments.

KEYWORDS
West African Dwarf goats, heat stress, regression analysis, Red Sokoto goats, physiological responses

INTRODUCTION

There are now threats that are negatively affecting the sustainability of livestock and currently making and creating the system as a result of climate variations and global warming. Climate change causes or gives rise to intimidating and threatening challenges to the enlargement of the livestock sector[1]. The international panel for climate change (IPCC) revealed an escalation and surge in temperature by 0.2°C per decade and estimated that the surface temperature of the earth might increase between 1.8°C to 4°C by the end of this century[2].

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Stress has been contrived as an involuntary reaction that happens inescapably when animals are susceptible or vulnerable to unfavourable environmental conditions and is the cause behind several undesirable or negative outcomes, ranging from hurt or discomfort to mortality of the animal[3]. Climate change-related temperature increases and earlier precipitation are expected to exacerbate heat stress in animals, which would lower their ability to reproduce and be productive[4,5]. Even though ruminants have a highly developed thermoregulation mechanism, they do not maintain severe homoeothermic conditions under stress. High ambient temperature, sun radiation and humidity are environmental stressors that increase or renew the load on animals[6]. High environmental temperature evokes, arouses, or confronts the ability of the animals to preserve and protect the hormonal and mineral balance, energy, water and thermal[7]. The body's reaction to stimuli that constantly interfere with homeostasis resulting in detrimental effects is referred to as stress.

Among all the stress factors, thermal stress is currently causing extreme worry during this dynamic climatic context or milieu. In sub-tropical and tropical regions, a rise in immediate environmental temperature is a remarkable challenge to animal production, however, extremely low, damaging and dangerous temperatures in temperate climates can injure and even kill livestock. Thermal stress includes both cold stress in the winter and heat stress in the long, brutal summer. Increases in the immediate surrounding temperature are particularly concerning in tropical and desert settings, but extremely low environmental temperatures in temperate locations can also be dangerous. Since temperature controls and affects heart rates, metabolic rates and other crucial aspects of an animal's physiology, a sudden temperature change can swiftly induce pain.

The impact of rising temperatures is compounded when heat stress is preceded or accompanied by high immediate surrounding humidity. The goat is the oldest domesticated species on the Indian subcontinent, having been tamed since 9000 BC[8]. Thousands of poor livestock owners earn their living by keeping goats in a variety of terrains and climatic circumstances all over the world. Goat rearing, a traditional activity of tiny, marginal farmers and landless labourers in developing countries' semiarid arid and hilly mountain regions, is unfriendly and antagonistic to traditional or archetypal crop production.

Comparing goat husbandry to other animal production methods reveals a number of benefits. The goat is India's primary meat-producing animal and is referred to as the "poorest man's cow" due to its nutritious milk[5]. It may be the only livestock used effectively in various socioeconomic situations or state affairs in developing countries. Goats are known to be better at coping with extreme weather than their domestic counterparts[9]. This ability to combat climatic change is multifactorial[10]. Goats are able to survive in harsh climates due to a variety of factors, including their small size and low body mass, low metabolic preconditioning, the tendency to reduce metabolism, digestive efficiency in comparison to feeding strategies, the efficiency of high fiber forage utilization, ability to economize nitrogen requirement and efficient use of water.

Although goats are more resistant to thermal stress than humans, they are nonetheless susceptible to heat and cold stress when temperatures rise above their comfort zone, which for Indian goats is between 13 and 27°C Celsius. Goats kept in open fields for most of the day are prone to environmental stress. This study was conducted to identify the regression analysis of physiological responses of indigenous breeds of goats (West African Dwarf and Sokoto Red) to heat stress in Nigeria.

MATERIALS AND METHODS

Study area: Samples and data from the animals were collected from various farm locations in Osun, Oyo and Kwara States respectively in Nigeria, from August 2018-February 2019 at the noon period in the day. The laboratory analysis was conducted at the Bio-safety Research Laboratory of the Federal University of Technology, Akure, Ondo State.

Experimental animals: Four hundred animals were experimented in this study. This comprises two hundred West African Dwarf and two hundred Red Sokoto breeds of goats, which are principally found in the South-West and Northern regions of Nigeria, respectively.

Experimental animals and their management: The research was focused on apparently healthy West African Dwarf (WAD) and Red Sokoto breeds of goats. These breeds in the agro-ecological zone are usually reared under extensive or semi-intensive husbandry where the animals are occasionally fed with cassava peels, corn shafts, kitchen waste, crop residues and most often on rubbish heaps. This rearing technique is modified and redesigned by the people in this community to lessen or minimise the struggle or strive between humans and goats for food. Adequate records were not kept on the animals. The practices of ethno-veterinary medicine were generally widespread.

Measurement of physiological parameters in Nigeria indigenous goats: The 200 West African Dwarf (WAD) goats and 200 Red Sokoto were sampled in Osun, Oyo and Kwara states. Rectal temperatures (RTRT), respiration rate (RRRR) and heart rate (HRHR) of the sampled goats were recorded as physiological measures/criteria of heat stress. The hottest temperature of the day, ranging from 13.30 to 14.30, was used to record RRRR and HRHR. T he physiological responses in each group were recorded three times over 10-12 days. A digital clinical thermometer (accuracy, 0.1°C) was used to mark RTRT in percentage. The RRRR 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 (RRRR) and heart rate, phenotyping for heat stress susceptibility was carried out (HRHR). Individuals with RRRR 50 and HR 130 were identified as heat stress susceptible (HSS) phenotypes, whereas those with RRRR 30 and HR 100 were identified as heat stress tolerant (HST) individuals in adult goats on the distribution of RRRR and HRHR among breeds in the population.

Ethical consideration: In conducting research on regression analysis of physiological responses of red Sokoto and West African Dwarf goats to heat stress, all procedures involving animals have been conducted with utmost respect for their welfare, in compliance with national and international guidelines for the ethical treatment of animals in research.

Data analysis: Data collected from the physiological parameter measurements were analyzed using the SAS package. The linear model used is as shown below:

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

Where:
Y_{ij} = Single observation
μ = Overall mean (constant)
A_i = Fixed effect of breed
E_{ij} = Random residual error

Means were separated using Duncan's multiple range test.
Linear regression analysis between the parameters was also carried out, generating the coefficient of determination (R^2) to indicate the efficiency of the prediction. The regression model used was of the form

$$Y = a + bx$$

Where:
Y = Dependent variable
a = Intercept
b = Regression coefficient
x = Independent variable

RESULTS AND DISCUSSION

Table 1 shows the impact or effect of breed on the different physiological responses of red sokoto and WAD breads to differing levels of THI. Differences or discrepancies in physiological response measurements or calculations were significant ($p<0.05$) in heartbeat rate and rectal temperature, respectively. No significant difference was observed for respiration rate measurement. Differences in THI values or scores were significant across all indicators calculated, while Breed x THI interactive effect was remarkable and significant at heart beat rate ($p<0.05$) and respiration rate ($p<0.05$).

Table 1: Effect of breed on the physiological response to varying THI values in Red Sokoto breed and WAD

		THI effect					
Parameter	Breed	≤82.70	82.71-87.39	≥87.40	Breed	THI	Breed*THI
Heartbeat rate (bpm)	Red Sokoto	88.24±1.89[b]	87.21±2.21[b]	90.86±1.80[a]	0.002	0.000**	0.000**
	WAD	81.02±2.36[b]	81.22±2.11[b]	91.17±1.81[a]			
Respiration rate (bpm)	Red Sokoto	60.61±.2.71[a]	60.72±2.89[a]	74.43±3.06[b]	0.275	0.002**	0.004**
	WAD	63.27±2.44[a]	61.07±2.47[a]	71.91±2.01[b]			
Rectal temperature (°C)	Red Sokoto	38.73±0.13[a]	39.11±0.11[b]	39.41±0.13[b]	0.001	0.000**	0.449
	WAD	39.10±0.09[a]	39.61±0.10[b]	39.61±0.08[b]			

**Significant at 5% alpha level and [a, b]: significant difference at 5%

Table 2: Regression analysis of the effect of THI on the physiological response of Red Sokoto

Effect of THI on heartbeat rate of red Sokoto	Coefficient	Standard error	t-value	Sig.	R^2	Adjusted R2
Constant	-222.917	25.868	-8.617	0.001	0.623	0.618
THI	3.484**	0.305	11.419	0.001		
THI on respiration rate of Red Sokoto						
Constant	-196.293	36.989	5.307	0.001	0.36	0.352
THI	2.907**	0.436	6.663	0.001		
THI on rectal temperature of Red Sokoto						
Constant	31.673	1.894	16.722	0.001	0.157	0.147
THI	0.086**	0.022	3.841	0.001		

**Significant at 5% alpha level

Table 3: Regression analysis of the effect of THI on the physiological response of WAD

Effect of THI on heartbeat rate of WAD	Coefficient	Standard error	t-value	Sig.	R^2	Adjusted R^2
Constant	-156.744	17.174	-9.127	0.001	0.544	0.542
THI	2.744**	0.198	13.829	0.001		
THI on respiration rate of WAD						
Constant	-163.083	24.052	-6.781	0.001	0.359	0.355
THI	2.630**	0.278	9.464	0.001		
THI on rectal temperature						
Constant	31.848	1.269	25.089	0.001	0.187	0.180
THI	0.088**	0.015	6.027	0.001		

**Significant at 5% alpha level

Regression analysis of the effect of THI on the physiological response of Red Sokoto and WAD: Table 2 shows the results of the effect of THI on physiological responses of test Sokoto Red breed of goat using regression analysis. The result in the table shows that THI had a positive and significant ($p<0.05$) effect on the heartbeat rate of the Red Sokoto breed. The R^2 value (0.623) shows that THI explains a 62.3% variation in the heartbeat rate of test Red Sokoto. The result in the table also shows that THI had a positive and significant ($p<0.05$) effect on the respiration rate of the Red Sokoto breed. The R^2 value (0.36) shows that THI explains a 36% variation in the respiration rate of test Red Sokoto. The result in the table further shows that THI had a positive and significant ($p<0.05$) effect on the rectal temperature of the Red Sokoto breed. The R^2 value (0.157) shows that a 15.7% variation in rectal temperature of the test Red Sokoto breed is explained by THI. This implies that THI is positive and significantly related to the physiological responses of the Red Sokoto breed of goat.

Regression analysis of the effect of THI on the physiological response of WAD: Table 3 shows the empirical results of the effect of THI on physiological responses of test WAD breed of goat using regression analysis. The result in the table shows that THI had a positive and significant ($p<0.05$) effect on the heartbeat rate of the WAD breed. The R^2 value (0.544) shows that THI explains a 54.4% variation in the heat beat rate of the test WAD breed. The result in the table also shows that THI had a positive and significant ($p<0.05$) effect on the respiration rate of the WAD breed. The R^2 value (0.359) shows that THI explains a 35.9% variation in the respiration rate of the test WAD breed. The result in the table further shows that THI had a positive and significant ($p<0.05$) effect on the rectal temperature of the WAD breed. The R^2 value (0.187) shows that THI explains an 18.7% variation in the rectal temperature of the test WAD breed. This implies that THI is positive and significantly related to the physiological responses of the WAD breed of goat.

Physiological parameters and temperature humidity index: The critical temperatures of 24-27°C are less than that of ambient temperature throughout the study for almost all of the animal species[11]. There is a similar case with the THI, which is much higher throughout the study period than 25.6 as reported by Marai *et al.*[12] as the benchmark for the severity of extreme heat stress. This signifies that all the goats were heat-stressed during the test period. This result was in line with many studies that reported higher THI values for animals in the tropics. However, it is reported from the study by and Broucek *et al.*[13] that THI values were higher on days without rain, which was also the same situation throughout the test period. Habeeb *et al.*[14] also recorded their results similar to other authors, claiming that the THI values increased from morning to evening, while relative humidity values decreased from morning to evening in the tropics and animals experienced heat stress throughout the whole day. In tropical and arid locations, heat is a critical and substantial challenge for animal output[15,16]. The over-heartbeat rate and the rectal temperature fell within the normal range for goats (70-90 beats per minute and 39-40°C, respectively, as reported by Pagot[17]. The measurement of the respiration rate throughout the study was higher than the resting respiration rate of goats (12-20 per minute) as reported by Alhidary *et al.*[18].

Overall heart beat rate, rectal temperature and respiration rates changed significantly with increasing THI values. The heart beat rate was high at high THI values and increased significantly as THI increased. Both respiration and rectal temperature increased with increasing THI. The results for the physiological parameters were similar at the breed level. The heartbeat rate, respiration rate and rectal temperature increased significantly with increasing THI values. These findings for heartbeat rate were against the finding of Adedeji[19], which recorded a decreased as environmental temperature increased. The initial rise is due to increased blood flow from the fundamental to the surface, allowing more heat to be dissipated through sensible (conduction, convection and radiation) and insensible (diffusion of water from the skin) ways. This was consistent with Titto *et al.*[20] observations that ewes' heart rates increased during the peak hour of the heat load. The latter decrease could be attributed to a decrease in metabolic and physical activity in response to the increasing thermal environment, which the animal used to reduce heat production[21].

The observed elevated respiratory rate in goats may have developed as a result of their attempt to dematerialize or evaporate body heat by panting, as respiratory evaporation is a significant evaporative heat loss channel or strategy in poultry or ruminants. Goats, cattle and sheep[22] have all been documented to exhibit elevated respiration in response to heat stress. The quick response of goats to environmental stress is an increase in respiratory rate[23].

The increase in the rectal temperature also progresses with increasing THI values which backed up the suggestion that with an increase in thermal environmental conditions, animal thermoregulatory efficiency is reduced, leading to a progressive increase in body temperature[24]. The breed effect analysis revealed that variances in measurement between the two breeds were only significant in rectal temperature measurements.

Regression analysis of the effect of THI on the physiological response of Red Sokoto and WAD: The regression analysis showed that THI had a positive and significant ($p \leq 0.05$) effect on the heartbeat rate of the Red Sokoto breed. The R^2 value (0.623) shows that THI explains a 62.3% variation in the heartbeat rate of test Red Sokoto. The THI had a positive and significant ($p \leq 0.05$) effect on the respiration rate of the Red Sokoto breed. The R^2 value (0.36) shows that THI explains a 36% variation in the respiration rate of test Red Sokoto. The THI had a positive and significant ($p \leq 0.05$) effect on the rectal temperature of the Red Sokoto breed. The R^2 value (0.157) shows that a 15.7% variation in rectal temperature of the test Red Sokoto breed is explained by THI. This implies that THI is positive and significantly related to the Red Sokoto breed of goat physiological responses.

The result of the regression analysis shows that THI had a positive and significant ($p < 0.05$) effect on the heartbeat rate of the WAD breed. The R^2 value (0.544) shows that THI explains a 54.4% variation in the heat beat rate of the test WAD breed. The result revealed that THI had a positive and significant ($p < 0.05$) effect on the respiration rate of the WAD breed. The R^2 value (0.359) shows that THI explains a 35.9% variation in the respiration rate of the test WAD breed. It was further revealed that THI had a positive and significant ($p < 0.05$) effect on the rectal temperature of the WAD breed. The R^2 value (0.187) shows that THI explains an 18.7% variation in the rectal temperature of the test WAD breed. This implies that THI is positive and significantly related to physiological responses of the WAD breed of Goat [21].

The current situation or state of affairs necessitates the development of techniques to enhance goats' adaptability to heat stress for them to show or demonstrate their full genetic potential. The goats' productivity is severely hampered by exposure to high temperatures. This situation or condition of affairs is more prevalent in tropical and subtropical places exposed to direct sunlight. High immediate surrounding temperature, accompanied or followed by high humidity, results in a loss in feed efficiency and consumption, as well as conflicting energy homeostasis, hormone secretions and blood metabolite creation, among other things. This results in direct and indirect forfeiture or deprivation for livestock owners by lowering chevon quality, reducing milk supply and impairing reproductive performance. To create appropriate strategies, a deeper understanding of the goats' adaptations to heat stress is required. It is the peak time for new strategies to be formulated to enhance the heat tolerance capacity of goats without compromising productivity. According to the authors, comprehensive research in this area requires time.

CONCLUSION

The maintenance of thermoneutrality is an essential aspect of the efficient productivity of the goats. Consequently, it is important to increase feed intake with substantial feed utilization for genetic advancement in meat production. To maintain physiological and biochemical balance, this large or significant feed intake typically leads to a larger metabolic heat rise, necessitating the use of an extremely effective thermoregulatory strategy. Heat stress is the result of a high metabolic heat rise that either initiates or is followed by various adaptive mechanisms. Diversified or differing physiological, biochemical and molecular reactions impede or obstruct the measurement of the actual enormity or proportion of the heat stress level in goats. Heat stress alters or adjusts energy metabolism and water and mineral (Na^+, K^+, Cl^-) metabolism through behavioral responses such as sweating, altered urination and defecation, increased water intake and drinking frequency.

SIGNIFICANCE STATEMENT

Goats can survive in harsh climates due to their small size, low body mass, metabolic efficiency, high fiber forage utilization, nitrogen economization and efficient water use. This study analyzed the physiological responses of Red Sokoto and West African Dwarf goats to heat stress in Nigeria. The regression analysis showed that the temperature-humidity index (THI) significantly increased heart rate, respiration rate and rectal temperature in both breeds. These physiological adaptations enable goats to thrive in harsh environments.

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