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Global Animal Science and Zoology OPEN ACCESS JOURNAL

DOI: https://dx.doi.org/10.17352/gasz

Research Article

Variability of Sexual Dimorphism on Morpho-Physiological Traits in Two Nigerian Indigenous Goat Breeds at Different Ages in Humid Tropical Climate

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Received: 08 August, 2025
Accepted: 22 August, 2025
Published: 23 August, 2025

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Keywords: Goat production; Physiological status; Thermoregulation; Breeding plans and Management

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Abstract

The contribution of small ruminants to household and national economies in sub-Saharan Africa is substantial. This study evaluated the variability of morphophysiological traits related to sexual dimorphism in two Nigerian indigenous goat breeds at various ages under intensive management. Eighty goats (30 WAD, 50 RS), approximately aged 150 days, were used over 12 weeks at the Goat Production Unit, Livestock Section, Teaching and Research Farm, Federal University of Technology, Akure, Nigeria. A 2×2 factorial experiment in a completely randomized arrangement was used to assess the influence of breed and sex on growth and physiological traits of the goats using SAS 2008 statistical software. Results showed that breed, sex, and age factors significantly ($p < 0.05$) influenced body weight and feed conversion ratio, with WAD goats showing superior growth traits over their RS counterparts. The WAD goats also demonstrated better thermoregulatory efficiency, evidenced by lower body temperatures. Conversely, RS goats had significantly higher ($p < 0.01$) pulse and respiratory rates, indicating breed-specific metabolic responses. The does consumed more feeds with higher body weight than males, while males had higher rectal temperatures, suggesting greater heat stress. The findings underscore the importance of breed- and sex-specific management in optimizing goat productivity. The WAD goats are recommended for environments with limited feed resources and high ambient temperatures. Conservation and genetic improvement of both breeds should target growth rate, feed efficiency, and thermoregulation especially at maturity. This study provides critical insights for designing sustainable breeding strategies to enhance goat production in the humid tropics of Africa.

Abbreviations

WAD: West African Dwarf; RS: Red Sokoto; °N: Degree North; °E: Degree East; °C: Degree Celsius; %: Percentage; mm: Millimeter; FCR: Feed Conversion Ratio

Introduction

Goat farming, like in many developed economies, is a critical component of livestock agriculture in Nigeria, contributing significantly to the livelihoods of rural populations and the national economy. Goats are especially valued for their adaptability to diverse agro-environmental conditions, resistance to diseases, and ability to thrive on minimal resources [1]. These attributes make goats an ideal livestock species in Nigeria, where harsh climatic conditions and limited resources often challenge agricultural productivity [2]. Nigeria

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Available from: https://dx.doi.org/10.17352/gasz.000002

is home to several indigenous goat breeds, including the West African Dwarf, Red Sokoto, and Sahelian goats, each adapted to specific ecological zones [3].

Despite the potential of these breeds, productivity levels are generally low, primarily due to inadequate management practices, poor nutrition, and lack of genetic improvement programmes [4]. The performance and physiological traits of goats are influenced by both genetic and non-genetic factors. For instance, breed differences affect growth rate, reproductive performance, and resistance to diseases [5]. Additionally, sex differences play a crucial role in determining traits such as growth rate, feed intake, weight gain, carcass yields, and feed conversion efficiency [6]. Male goats typically exhibit faster growth rates and higher carcass yields than females, making them more suitable for meat production [7]. Achieving greater productivity would equally involve adequate studies of physiological parameters via pulse rate, respiratory rate, body temperature, and rectal temperature, which are critical indicators of health, metabolic activity, and stress response in goats [8]. Their relationship to feed consumption, body growth, and overall health physiology is foundational in both research and farm management. In recent years, there has been growing interest in optimizing goat production through the selection of appropriate breeds and the implementation of improved management practices. However, there is still a significant gap in the literature regarding the specific impacts of breed and sex on the performance and physiological characteristics of these Nigerian goat breeds [9,10]. Understanding these relationships is essential for developing targeted breeding programmes and management strategies that enhance goat productivity and sustainability in Nigeria [11].

Therefore, this study seeks to provide analytical results of the effects of breed and sex on the performance and physiological traits of West African Dwarf and Red Sokoto goats, Nigerian indigenous goat breeds. These findings could significantly contribute to or serve as baseline data that can ultimately be used to improve goat production in Nigeria via strategic breeding programmes and management practices.

Materials and methods

Location of study

The research was carried out at the Small Ruminant Unit of the Teaching and Research Farm of the Federal University of Technology, Akure. The area is located between 6.91°N and 5.15°E. The climatic condition of Akure follows the pattern of South-West Nigeria, where the climate is influenced mainly by the rain-bearing Southwest monsoon winds from the ocean and the dry Northwest winds from the Sahara Desert. The rainy season lasts for about seven months (April to October). The temperature throughout the year ranges between 21 and 29 °C, while the relative humidity is 77.1%. The annual rainfall varies from 1,150 mm to 2,000 mm [12].

Pre-experimental operation

To ensure optimal animal welfare and biosecurity, existing goat houses and pens were thoroughly inspected and repaired as necessary. The facilities required for the study were cleaned and disinfected to minimize the risk of disease transmission. Appropriate feeding and watering systems were put in place, and essential measuring equipment, including weighing scales, thermometer, and stethoscope, was made readily available to facilitate smooth operations throughout the experimental period.

Animal procurement sample size and experimental layout

A total of 80 goats with an average age of 150 days old were purchased from trusted local farmers close to the University community to reduce transportation-related stress. The animals were reared under controlled conditions and used for the study at the Goat Production Unit, Livestock Section of the Teaching and Research Farm, the Federal University of Technology, Akure, Nigeria, over 12 weeks. There were two breeds (treatments) of five replicates at 3 and 5 goats per replicate, making a total of 15 and 25, respectively, for WAD and RS goats. The treatment was doubled into an equal number of males (bucks) to females (does) ratio, totaling 30 WAD and 50 Red Sokoto goat breeds. Upon arrival on the farm, the goats underwent a quarantine period, during which they were isolated, screened for diseases, and a multivitamin was administered thereafter. Following quarantine, the goats were gradually acclimatized to the farm environment, ensuring a smooth transition into the experimental conditions. Each goat was given a unique identification number, which helped in the accurate tracking of their health, data entry, and all other relevant details throughout the experiment. This ensured that accurate records were taken and that the animals were well-kept in preparation for the study.

Management practices

An intensive farming system was employed to manage the goats during the study. The goats were housed in secure, well-ventilated pens, with regular cleaning and disinfection to maintain hygiene. Bedding was replaced weekly to prevent the build-up of waste and minimize disease risks. The goats were provided with a measured concentrate diet and supplemented with forage *ad libitum* to meet their nutritional needs. Feed was allocated in controlled portions, ensuring precise intake, while water was supplied *ad libitum* to ensure constant availability. Dietary changes were introduced gradually to prevent digestive issues. The percentage composition of the concentrates given to the goats is represented in Table 1. Health management was a top priority, with routine deworming and drug administration carried out at the appropriate time to ensure the animals remained in their optimal health condition. Immediate attention was given to any signs of illness to prevent the outbreak of diseases. Accurate records of all management activities, including feeding and health treatments, were maintained using the unique identification numbers assigned to each goat.

Data collection

Growth performance and physiological data were systematically collected at specific ages on live experimental

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Table 1: Gross composition of concentrate feed (%).

Ingredients	Composition
Cassava Peel Meal	50.00
Wheat Offa	34.00
PKC	13.00
Urea	1.00
salt	0.50
Premix	0.50
DCP	1.00
Total	100.00

animals during the period of this study to evaluate the growth and physiological performances of the goats. The data were evaluated to provide a comprehensive analysis of the effects of breed and sex on the selected parameters.

Growth performance data

Performance measurements were taken regularly to evaluate the overall productivity of the goats. The parameters recorded include:

Bodyweight: Goats were weighed weekly using a digital weighing scale to track weight changes and assess overall growth performance. Regular body weight measurements provide critical insights into the effectiveness of feeding regimens and overall health.

Feed intake: Feed was supplied *ad libitum*, though weighed, and the total amount of feed consumed by each goat daily was measured by deducting the leftovers from the quantity supplied. Feed intake data were recorded to evaluate feeding patterns and determine feed efficiency. This information is essential for assessing how much feed is required for optimal growth.

Feed Conversion Ratio (FCR): The FCR is calculated as the amount of feed consumed per unit of weight gained. This was used to assess the efficiency with which the goats convert feed into body mass. Lower FCR values indicate better feed efficiency, which is economically important in livestock production.

Health status: The general health of each goat was monitored throughout the experiment. Any signs of illness, lameness, or abnormalities were documented. Health status affects performance, as healthy animals typically exhibit better growth and productivity.

Water consumption: Water intake was provided *ad libitum* and was monitored to ensure adequate hydration for optimal performance. Water consumption is a key factor in maintaining physiological function and ensuring healthy growth rates.

These performance measurements were critical for understanding the efficiency of feed utilization, growth potential, and overall health of the goats. By analyzing these data, the study aimed to provide insights into how breed and sex differences influence the performance and productivity of the Nigerian indigenous goat breeds under an intensive management system. For this study, key performance parameters such as body weight, Feed Intake, and feed conversion ratio (FCR) were prioritized.

Physiological data

Physiological data were collected and recorded appropriately to assess the goats' responses to environmental and management conditions. The following parameters were monitored:

Pulse rate: Measured manually by palpating the femoral artery.

Respiratory rate: Counted as the number of breaths per minute.

Body temperature: Measured using a non-contact infrared thermometer.

Rectal temperature: Measured using a digital rectal thermometer.

These physiological indicators helped in assessing the overall health and stress levels of the animals throughout the experimental period.

Statistical analysis

All data collected were subjected to factorial analysis of variance using [13] to determine the effects of breed, sex, and their interactions. Where significant differences existed, the means were separated using Duncan Multiple Range Test of the same statistical package.

Results

Effect of sex on growth performance of Red Sokoto and West African Dwarf goat breeds at week two

The effects of sex on the growth performance of Red Sokoto (RS) and West African Dwarf (WAD) goat breeds at week two in this study are shown in Table 2. The breed of goats in this study significantly ($p < 0.05$) influenced the growth parameters measured. The RS goats (8.75 kg) have significantly ($p < 0.05$) higher initial weights than the WAD (8.62 kg) goats. This indicated that RS goats may be bred or managed to heavier weights than the WAD goats. Although, there were no significant differences ($p > 0.05$) in the final weights (9.18 kg RS *vs.* 9.08 kg WAD) and total feed intake (2.70 kg RS *vs.* 2.15 kg WAD) of the goats, the parameters have higher numerical values compared to WAD goats, showing that the RS goats consumed more feed at this age than their WAD counterparts. However, the WAD goats performed better numerically but not statistically in TWG (0.43 kg RS *vs.* 0.45 kg WAD) and FCR (6.55 RS *vs.* 4.92 WAD) than the RS goats. This means that WAD goats could gain and weigh more than RS goats under similar management circumstances, which could form a valuable basis for breed-specific selection when planning goat improvement programmes. Sex exerted a superior and significant ($p < 0.05$) influence on total feed intake (2.61 kg Does *vs.* 2.24 kg Bucks),

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initial (9.47 kg Does *vs.* 7.90 kg Bucks), and final (9.98 kg Does *vs.* 8.28 kg Bucks) weights, where the female goats had higher values compared to males. Despite the differences in feed intake, weight gain, and FCR were not significantly different ($p > 0.05$) between the sexes, although does showed numerically higher weight gain and better feed conversion ratio than the bucks. This result indicated that does may be born or managed to heavier weights and consume more feeds than the bucks, underscoring the selection for female goats in planning goat improvement programmes. A significant interaction ($p < 0.01$) between breed and sex was observed for initial weight. The WAD had the highest initial weight (9.55 kg) while the WAD bucks had the lowest (7.70 kg). No significant ($p > 0.05$) interactions were observed for the other growth parameters.

Effect of sex on performance characteristics of two Nigerian indigenous goat breeds at week six

The Performance characteristics of Red Sokoto (RS) and West African Dwarf (WAD) goats based on breed and sex in Week 6 are shown in Table 3. The parameters evaluated were significant. influenced ($p < 0.05$ by breed and sex factors. The breed of goats did not significantly ($p > 0.05$) influence any of the parameters measured in Week 6. However, the RS goats showed superior numerical increase than their WAD counterparts with records of Initial weights 9.18 kg (RS) *vs.* 9.08 kg (WAD), final weights 9.73 kg (RS) *vs.* 9.56 kg (WAD), total feed intake 3.40 kg (RS) *vs.* 3.09 kg (WAD), total weight gain 0.55 kg (RS) *vs.* 0.49 kg (WAD) and the FCR 6.13 kg (RS) *vs.* 7.57 kg (WAD) for the measured parameters. The sex had a significant ($p < 0.05$) influence on total feed intake and final weight performance, where the does recorded higher final weights (10.44 kg) compared to the bucks (8.85 kg). This could be due to the onset of development or expression of certain hormonal differences in the body system. However, the initial weight, total weight gain, and feed conversion ratio were not significantly different ($p > 0.05$). There was no significant interaction ($p > 0.05$) between breed and sex for all the parameters measured in these animals at this age.

Effect of sex on performance characteristics of Red Sokoto and West African Dwarf goats at week twelve

The variability of sex on the performance of Red Sokoto and West African Dwarf (WAD) goat breeds in week 12 is shown in Table 4 below. The parameters evaluated were significantly influenced ($p < 0.05$) by the breed and the interaction between breed and sex of the goats. The Red Sokoto goats generally

Table 2: Effects of breed, sex and interaction on the performance of goats at week two of the trial.

BREED	SEX	IWT (Kg)	FWT (Kg)	TFI (Kg)	TWG (Kg)	FCR
RS		8.75[a]	9.18	2.70	0.43	6.55
WAD		8.62[b]	9.08	2.15	0.45	4.92
±SEM		0.32	0.33	0.09	0.06	0.58
p - value		0.05	0.80	0.84	0.78	0.12
	Male	7.90[b]	8.28[b]	2.24[b]	0.38	6.43
	Female	9.47[a]	9.98[a]	2.61[a]	0.50	5.04
	±SEM	0.32	0.33	0.09	0.06	0.58
	p - value	0.04	0.03	0.02	0.21	0.16
RS	Male	8.10	8.40	2.19	0.30	7.28
	Female	9.40	9.95	3.22	0.55	5.82
WAD	Male	7.70	8.15	2.30	0.45	5.58
	Female	9.55	10.00	2.00	0.45	4.25
	±SEM	0.45	0.47	0.12	0.08	0.82
	p - value	0.01	0.58	0.76	0.21	0.94

[Means] with different superscripts on the same column for the same parameter are significantly ($p < 0.05$) different, ±SEM: Standard Error of Mean; IWT: Initial Weight; FWT: Final Weight; TFI: Total Feed Intake; WG: Weight Gain; FCR: Feed conversion Ratio; RS: Red Sokoto and WAD: West African Dwarf

Table 3: Effects of breed, sex, and interaction on the performance of goat breeds at week six of the trial.

BREED	SEX	IWT (Kg)	FWT (Kg)	TFI (Kg)	TWG (Kg)	FCR
RS		9.18	9.73	3.40	0.55	6.13
WAD		9.08	9.56	3.09	0.49	7.57
±SEM		0.33	0.37	0.19	0.09	0.61
p - value		0.32	0.84	0.77	0.65	0.17
	Male	8.28	8.85[b]	2.95[b]	0.58	5.45
	Female	9.98	10.44[a]	3.54[a]	0.46	8.25
	±SEM	0.32	0.33	0.09	0.06	0.58
	p - value	0.09	0.02	0.04	0.42	0.42
RS	Male	8.40	8.90	2.65	0.50	5.29
	Female	9.95	10.55	4.15	0.60	6.97
WAD	Male	8.15	8.80	3.26	0.65	5.60
	Female	10.00	10.33	2.93	0.33	9.53
	±SEM	0.47	0.52	0.27	0.13	0.86
	p - value	0.03	0.76	0.91	0.17	0.26

[Means] with different superscripts on the same column for the same parameter are significantly ($p < 0.05$) different, ±SEM: Standard Error of Mean; IWT: Initial Weight; FWT: Final Weight; TFI: Total Feed Intake; WG: Weight Gain; FCR: Feed conversion Ratio; RS: Red Sokoto and WAD: West African Dwarf

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recorded superior values than the WAD goats for the measured parameters.

However, significant differences ($p < 0.05$) between the two sexes existed only in the initial weight, final weight, and total feed intake parameters, where the female goats grew faster, consumed more feed, gained more weight, and weighed heavier than the male goats at nearly a yearling age of their lives. This observation could be due to the onset of development or expression of hormonal differences in the body system that make the bucks concentrate more attention on the does rather than on feed consumption to maintain their growth physiology. Similar to the observation of records at week 6 of this study, significant interactions ($p < 0.05$) between breed and sex were noticed for weight gain and FCR.

PhysBiological characteristics of Red Sokoto and West African Dwarf goats based on sex at week two

Table 5 shows the effects of sex on physiological parameters measured for both Red Sokoto (RS) and West African Dwarf (WAD) goats, which include the body weight, respiratory rate, pulse rate, rectal temperature, and body temperature. The physiological traits of RS and WAD goats provide valuable insights into the variations between the two breeds regarding how they respond to environmental and physiological changes or conditions. The WAD goats had slightly higher average body weight (16.16 kg) than to RS Goats (14.71 kg). However, the difference between breeds was not statistically significant ($p > 0.05$). Although the WAD goats (38.92 °C) displayed a higher rectal temperature than RS goats (36.96 °C), the difference was not statistically significant ($p > 0.05$). There was a significant difference ($p < 0.05$) between the two breeds, with SR goats having a higher respiratory rate (57.44 breaths/minute) than WAD goats (53.60 breaths/minute). The pulse rate showed a highly significant difference ($p < 0.01$) between the breeds. Red Sokoto goats had a significantly higher pulse rate (59.37 beats/minute) than the WAD goats (53.48 beats/minute). There was a highly significant difference in body temperature ($p < 0.001$) between the breeds, where WAD goats recorded higher body temperature (38.62 °C) compared to RS goats (37.85 °C). Sex based differences across the measured physiological traits showed that females had a higher average body weight (16.22 kg) than males (14.66 kg), but this difference was not statistically significant ($p > 0.20$). This indicated that sex did not significantly affect body weight between the two goat breeds in this study at this age. Similarly, the respiratory

Table 4: Effects of breed, sex, and interaction on the performance of goats at week twelve of the trial.

Breed	Sex	IWT (Kg)	FWT (Kg)	TFI (Kg)	TWG (Kg)	FCR
RS		9.73	10.63	3.21	0.53	6.12
WAD		9.56	10.05	3.29	0.50	6.94
±SEM		0.37	0.40	0.16	0.04	0.35
p - value		0.73	0.39	0.36	0.07	0.68
	Male	8.85^{b}	9.38^{b}	2.84^{b}	0.53	5.51
	Female	10.85^{a}	11.30^{a}	3.66^{a}	0.50	7.55
	±SEM	0.32	0.33	0.09	0.06	0.58
	p - value	0.03	0.02	0.02	0.06	0.68
RS	Male	8.90	9.35	2.59	0.45^{b}	5.87^{a}
	Female	11.30	11.90	3.82	0.60^{a}	6.36^{b}
WAD	Male	8.80	9.40	3.08	0.60^{a}	5.15^{b}
	Female	10.40	10.70	3.50	0.40^{b}	8.73^{a}
	±SEM	0.52	0.56	0.23	0.06	0.50
	p - value	0.15	0.48	0.33	0.05	0.04

Means with different superscripts on the same column for the same parameter are significantly ($p < 0.05$) different, ±SEM: Standard Error of Mean; IWT: Initial Weight; FWT: Final Weight; TFI: Total Feed Intake; WG: Weight Gain; FCR: Feed conversion Ratio; RS: Red Sokoto and WAD: West African Dwarf

Table 5: Effects of breed, sex, and interaction on the physiological parameters at week two of the trial.

BREED	SEX	BWT (kg)	RR	PR	RT (°C)	BT (°C)
RS		14.71	57.44^{a}	59.37^{a}	36.96	37.85^{b}
WAD		16.16	53.60^{b}	53.48^{b}	38.92	38.62^{a}
±SEM		0.85	1.22	1.11	0.60	1.25
p - value		0.24	0.03	0.02	0.15	0.00
	Male	14.66	54.50	55.13	38.43	38.25
	Female	16.22	56.54	57.72	37.46	38.22
	±SEM	0.85	1.22	1.26	0.95	0.11
	p - value	0.20	0.24	0.15	0.47	0.84
RS	Male	13.65	57.00	58.50	38.12	38.04
	Female	15.78	57.88	60.24	35.80	37.66
WAD	Male	15.66	52.00	51.75	38.74	38.46
	Female	16.66	55.20	55.20	39.11	38.78
	±SEM	0.87	1.23	1.15	0.93	0.15
	p - value	0.64	0.51	0.63	0.32	0.07

Means with different superscripts on the same column for the same parameter are significantly ($p < 0.05$) different, different, SEM: Standard Error of Mean; BWT: Body Weight; RR: Respiratory Rate; PR: Pulse Rate; RT: Rectal Temperature; BT: Body Temperature; RS: Sokoto Red; WAD: West African Dwarf.

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rate was slightly higher in females (56.54 breaths/minute) than in males (54.50 breaths/minute), but the difference was not statistically significant ($p > 0.24$). Female goats showed slightly higher pulse rate (57.72 beats/minute) than males (55.13 beats/minute). However, this difference was not statistically significant ($p > 0.15$). The bucks had a higher rectal temperature (38.43 °C) than the does (37.46 °C), and the difference was not statistically significant ($p > 0.47$). This implied that rectal temperature was relatively similar between sexes for both breeds. There was no significant difference in body temperature between males (38.25 °C) and females (38.22 °C) ($p > 0.835$). The interaction between breed and sex showed that male Red Sokoto goats had a lower body weight (13.65 kg) than females (15.78 kg), but the difference was not significant. Respiratory and pulse rates were not statistically significant ($p > 0.05$). Rectal temperature was higher in males (38.12 °C) than in females (35.80 °C), but also not significant. Body temperature was comparable between sexes in Red Sokoto goats. Females had slightly higher body weights (16.66 kg) than males (15.66 kg), but the difference was not significant. Females also have higher respiratory and pulse rates than males, but the differences were not significant. Female WAD goats had a higher rectal temperature (39.11 °C) than males (38.74 °C), but the difference was not significant either. Body temperature was slightly higher in females (38.78 °C) than in males (38.46 °C), with the difference approaching significance ($p > 0.07$).

Effect of sex on the physiological characteristics of two indigenous Nigerian goat breeds at week six

As shown in Table 6, the WAD goats had a higher average body weight (16.81 kg) than the Red Sokoto (RS) goats (15.00 kg). The difference was not statistically significant ($p > 0.12$). The RS goats had a significantly ($p < 0.01$) higher respiratory rate (61.03 breaths/min) than the WAD goats (49.80 breaths/min), indicating a highly significant difference. Similarly, Sokoto Red goats had a significantly ($p < 0.01$) higher pulse rate (61.01 beats/min) than WAD goats (50.35 beats/min). The rectal temperatures of both breeds were fairly similar, with Red Sokoto goats at 37.73 °C and WAD goats at 38.15 °C . The difference was not statistically significant ($p > 0.23$), suggesting that both breeds maintain similar core body temperature under the same conditions. The body temperature of Red Sokoto goats at 37.76 °C and WAD goats at 37.99 °C showed that the difference was not significant ($p > 0.51$). The effect of sex on the female goat's body weight (17.06 kg) was significantly ($p < 0.05$) higher than male goats (14.75 kg), suggesting a notable difference in body weight based on sex differential. On the respiratory rate (breaths/min), there was no significant difference ($p > 0.64$) between male (55.85 breaths/min) and female (54.98 breaths/min) goats. The pulse rate (beats/min) of female goats tended to have a higher pulse rate (57.31 beats/min) than males (54.05 beats/min), but the difference was not statistically significant ($p > 0.06$). The rectal temperatures of male (37.90 °C) and female (37.99 °C) goats were almost the same, with no significant difference ($p > 0.80$). There was no significant difference ($p > 0.40$) in body temperature between males (38.02 °C) and females (37.72 °C) . For breeds and sexes, WAD females had the highest body weight (17.80 kg) while Red Sokoto males had the lowest (13.69 kg), but the differences between sexes within the same breed were not statistically significant ($p > 0.77$). Pulse Rate showed significant differences in some cases, with WAD females having lower pulse rates than Red Sokoto females ($p < 0.02$). No significant interactions were observed for respiratory rate, rectal, or body temperatures between breed and sex ($p > 0.05$).

EfEffect of sex on the physiological characteristics of two Nigerian goat breeds at week twelve of the trial

The physiological data collected in week 12 of the experiment highlights significant differences between the two Nigerian goat breeds, Red Sokoto (RS) and West African Dwarf (WAD) goats, as well as differences between male and female goats for various physiological traits, including body weight, respiratory rate, pulse rate, rectal temperature, and body temperature as shown in Table 7. The WAD goats demonstrated a significantly ($p < 0.04$) heavier average body weight (18.73 kg) than RS goats (16.05 kg), indicating that the WAD breed had a notable advantage in body mass. Likewise, the female goats in both breeds were significantly ($p < 0.04$) heavier (18.74 kg) than

Table 6: Effects of breed, sex, and interaction on the physiological parameters at week six of the trial.

BREED	SEX	BWT (kg)	RR	PR	RT (oC)	BT (oC)
RS		15.00	61.03[a]	61.01[a]	37.73	37.76
WAD		16.81	49.80[b]	50.35[b]	38.15	37.99
±SEM		0.79	1.28	1.17	0.24	0.87
p - value		0.12	0.01	0.01	0.23	0.51
	Male	14.75[b]	55.85	54.05	37.90	38.02
	Female	17.06[a]	54.98	57.31	37.99	37.72
	±SEM	1.27	1.04	1.22	0.31	0.90
	p - value	0.05	0.64	0.06	0.80	0.40
RS	Male	13.69	61.70	56.60	37.86	37.94
	Female	16.32	60.35	65.41	37.60	37.58
WAD	Male	15.81	50.00	51.50	37.94	38.10
	Female	17.80	49.60	49.20	38.37	37.87
	±SEM	0.87	1.22	1.14	0.93	0.17
	p - value	0.77	0.80	0.01	0.33	0.85

[ab]Means with different superscript on the same column for the same parameter are significantly ($p < 0.05$) different, SEM: Standard Error of Mean; BWT: Body Weight; RR: Respiratory Rate; PR: Pulse Rate; RT: Rectal Temperature; BT: Body Temperature; RS: Sokoto Red; WAD: West African Dwarf.

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Table 7: Effects of breed, sex, and interaction on physiological traits of experimental goats at twelve

BREED	SEX	BWT (kg)	RR	PR	RT (oC)	BT (oC)
RS		16.054b	62.88[a]	54.35	38.33[a]	38.14
WAD		18.73a	55.85[b]	55.45	37.84[b]	37.83
±SEM		0.69	0.43	1.19	0.14	0.16
p - value		0.038	0.000	0.081	0.015	0.207
	Male	16.04[b]	58.60	54.28[b]	38.37[a]	38.34[a]
	Female	18.74[a]	60.13	55.52[a]	37.79[b]	37.62[b]
	±SEM	1.20	1.10	1.24	0.31	0.91
	p - value	0.036	0.085	0.049	0.004	0.005
RS	Male	15.03	62.70	54.05	38.59	38.48
	Female	17.08	63.06	54.65	38.07	37.79
WAD	Male	17.06	54.50	54.50	38.16	38.20
	Female	20.39	57.20	56.40	37.51	37.45
	±SEM	0.67	1.28	1.05	0.88	0.25
	p - value	0.614	0.185	0.297	0.726	0.887

Means with different superscripts on the same column for the same parameter are significantly ($p < 0.05$) different, SEM: Standard Error of Mean; BWT: Body Weight; RR: Respiratory Rate; PR: Pulse Rate; RT: Rectal Temperature; BT: Body Temperature; RS: Sokoto Red; WAD: West African Dwarf.

males (16.04 kg). This finding underscores the influence of sex on body weight, where females generally have greater mass than their male counterparts. The result of the respiratory rate revealed a significant breed difference. Red Sokoto goats exhibited a higher respiratory rate (62.88 breaths per minute) than WAD goats (55.85 breaths per minute), with the difference being statistically significant ($p < 0.01$). This suggested that Red Sokoto goats had a more elevated rate of breathing, possibly due to differences in metabolism or environmental adaptations. However, the respiratory rate difference between sexes, although slightly higher in females (60.13 breaths per minute) than in males (58.60 breaths per minute), was not statistically significant ($p > 0.09$). For pulse rate, no significant differences ($p > 0.08$) were observed between the two breeds, with RS goats averaging 54.35 beats per minute and WAD goats averaging 55.45 beats per minute. Despite this, sexual differences were statistically significant ($p < 0.05$), with females having a higher pulse rate (55.52 beats per minute) compared to males (54.28 beats per minute). This suggested that female goats might have a slightly higher cardiovascular activity to overcome health-related stress compared to males. For rectal temperature, WAD goats had a significantly lower temperature (37.84 °C) than RS goats (38.33 °C), with the difference being statistically significant ($p < 0.02$). This breed difference indicated that WAD goats tend to maintain lower body temperatures, potentially due to metabolic or environmental factors. Rectal temperature was also significantly ($p < 0.04$) influenced by sex, with males showing a higher temperature (38.37 °C) than females (37.79 °C), highlighting that male tends to have slightly higher body temperatures than females. The analysis of body temperature did not reveal significant differences ($p > 0.21$) between the breeds, as RS goats had an average body temperature of 38.14 °C compared to 37.83 °C for WAD goats. However, sex differences were significant ($p > 0.01$) with males exhibiting higher body temperatures (38.34 °C) than females (37.62 °C). Also, the breed-sex interaction showed that within the RS goats, females had higher body weight, respiratory rate, and pulse rate than males, although none of these differences were statistically significant ($p > 0.05$). Similarly, the female WAD goats exhibited higher body weight, pulse rate, and lower rectal temperature than males, though these differences were not statistically significant ($p > 0.05$) for all traits. This suggests that while sex and breed independently influence physiological body functions, their interaction did not produce such distinct physiological outcomes.

Discussion

Effects of breed, sex, and interaction on the performance indices of experimental goats at various ages

The present study indicated that during the early to mid-growing period of up to eight months or more in goat rearing, breed did not significantly influence growth performance traits such as initial and final weights, total feed intake, total weight gain, and feed conversion ratio. This observation suggests that both RS and WAD goat breeds have comparable growth performances and feed utilization efficiencies under similar management conditions. This finding aligned with the observations of [14], who reported no significant differences in growth performance between different goat breeds in tropical regions. It should, however, be noted that there was a higher initial weight in RS goats, which could indicate potential breed differences in early growth rates. This subtle difference might be attributed to genetic factors or pre-study environmental conditions, as earlier opined by [15] in their study on the effects of breed in early goat development.

In contrast to the breed effect, sex had a more pronounced influence on the growth traits measured. Female goats consistently showed higher initial and final weights, with significant differences observed across the three selected weeks (two, six, and twelve) in this study. This sexual difference in body weight is consistent with the findings of [16], who reported that female goats tend to have higher body weights in certain

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breeds during the growing phase. Female goats demonstrated significantly higher total feed intake in weeks two and six. This increased feed consumption by females could be related to their higher body weights and potential differences in nutritional requirements. Similar observations were reported by [17] in their study on sex- based differences in goat feeding behaviour. Despite the differences in feed intake, weight gain did not differ significantly between males and females across the three selected weeks. This suggested that while females consumed more feed, they did not necessarily convert it more efficiently into body mass index. This finding is in contrast with the study of [18], who found that female goats had both higher feed intake and weight gain in certain breeds. The feed conversion ratio (FCR) did not show significant differences between sexes, indicating that both males and females had similar feed utilization efficiencies. However, there was a numerical trend towards lower FCR in females in weeks two and six, which aligned with the observations of [19] on sex-based differences in feed efficiency among small ruminants.

The interaction between breed and sex at week 12 revealed a significant effect on weight gain and FCR. The male WAD goats showed higher weight gain compared to the male Red Sokoto goats. The result of this interaction suggests that the effect of sex on growth performance might vary depending on the breed and age of the animal. This result corroborates that of [17] in their study on the comparative study of Nigerian goat breeds and their effect on sexual dimorphism. The FCR interaction in week twelve indicated that male WAD goats and female RS goats had more favorable (lower) FCR values than their respective counterparts.

Effects of breed, sex, and interaction on the physiological traits of experimental goats at various ages

IIt was shown in the present study that there was no significant difference in the body weights of the RS and WAD goat breeds. At week two, females showed significantly higher body weights than males, with no significant difference between breeds. At week four, WAD goats were significantly heavier in body weight than RS goats. Similarly, the female goats remained significantly heavier than the male goats. The higher weight in females can be linked to better growth and fat deposition in the WAD goats, which is consistent with previous studies on the breed's superior adaptability to local conditions [20].

The respiratory rate of Red Sokoto goats was significantly higher than that of WAD goats across the selected ages in this study, with no sexual differences observed. This could suggest that the Red Sokoto breed is more reactive to environmental stressors such as heat, as the respiratory rate increased with thermoregulatory responses. Similar findings had been reported by earlier researchers [21].

At week two, Red Sokoto goats exhibited higher pulse rates compared to WAD goats, which suggests a breed-specific physiological adaptation to manage circulation in response to external stimuli such as environmental changes. While at week six, the rate difference between breeds diminished, with female goats having a higher pulse rate than males. This difference between sexes aligned with the findings of [22], which noted that female animals generally exhibit higher pulse rates under heat stress conditions due to hormonal influences. The observation of Red Sokoto goats exhibiting higher respiratory and pulse rates suggests a less efficient physiological adaptation to stress conditions compared to the more heat-tolerant WAD goats. The WAD goats' superior adaptability is further supported by their greater weight gain over time.

There were no significant differences in rectal temperatures recorded between breeds or sexes at week two, but at week 4, Red Sokoto goats had a higher rectal temperature than WAD goats. Males also showed significantly higher rectal temperatures than females. The higher rectal temperature in Red Sokoto goats could suggest they experience more thermal stress, which affects core body temperature. Similar to reports that had earlier been made by [23] regarding livestock's heat tolerance differences. The WAD goats had a significantly higher body temperature than the RS goats during the initial period. This suggests that WAD goats are known for their superior adaptability to high ambient temperatures. This finding may have suggested that the WAD goats have a more efficient thermoregulatory mechanism [24]. At week four, males exhibited higher body temperatures than females, possibly due to increased hormonal activities or metabolic rates, which have been previously observed in goats [8]. These observations corroborate earlier findings that the WAD goats' physiological traits are better suited to tropical environments with higher heat stress, making them more resilient in such climates. On the other hand, RS goats might require more careful management and selection protocols in hotter conditions to improve their adaptability to heat heat-stress environment.

Conclusion

Breed, sex, and age play crucial roles in determining the growth and physiological traits of the two Nigerian indigenous goat breeds in this study. The study noted that the expression of certain growth traits was masked in early life and became pronounced as the goats advanced in age. The West African Dwarf goat breed demonstrated superior body weight gain, feed efficiency, and thermoregulatory mechanisms than the Red Sokoto breed. The does demonstrated superiority to the bucks in terms of growth rate and feed intake in both breeds. These differences explain the need for breed- and sex-specific management and selections to optimize breeding and improvement strategies for goat production in Nigeria. The results of the study offer valuable information for developing targeted breeding programmes aimed at improving the productivity and sustainability of goat farming in the humid tropical climate of Africa.

Recommendations

On the basis of this study and the distinct morpho-physiological merits of Sokoto Red and WAD goat breeds, it is important to prioritize their genes for conservation and improvement strategies through structured breeding programmes. The selection of the West African Dwarf goat

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breed is recommended for areas with limited or short feed resources due to its high feed efficiency over the Sokoto Red goats. The targeted breeding programmes should be focused on improving both sexes of the goat breeds by selecting for traits such as growth rate, feed efficiency, and thermoregulatory genes to ensure the sustainability and profitability of goat farming enterprises in Nigeria and sub-Saharan Africa.

Statements of ethical standard

All animals used for this experiment were humanely handled according to the ARRIVE (Animal Research Reporting of In Vivo Experiments) guidelines and were carried out by the UK Animals (Scientific Procedures) Act, 1986 and associated guidelines; EU Directive 2010/63/EU for animal experiments; or the National Institutes of Health guide for the care and use of laboratory animals (NIH Publications No. 8023, revised 1978) were followed. The sex and its association with the results of the study were included in the texts as appropriate.

Acknowledgement

The Authors appreciate EVEREST-FAPEMIG of the Minas Gerais State, Brazil, for the financial support received towards the publication of this article. We also appreciate Prof. L.A. Nero for the warm reception given to one of the authors at UFV and the enabling environment created that propelled the publication of this manuscript.

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