

Original Research Paper

Influence of breed, diet, and sex on growth performance of Nigerian indigenous goat breeds under tropical conditions

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ABSTRACT

This experiment was conducted to study the influence of breed, diet, and sex on the growth performance of Nigerian indigenous goat breeds under tropical conditions. A total of 36 weaner goats (3–4 months old), were assigned to a 2 x 3 x 2 factorial arrangement within a Completely Randomized Design (CRD). Each treatment combination was replicated 3 times (12 x 3 = 36 animals in total). The dietary treatments consisted of 100% *Digitaria smutsii* (DS), 50%DS+50% groundnut haulms (GH), and 50%DS+50% cowpea husk (CH). Growth performance parameters, including body weight, weight gain, feed intake, feed conversion ratio (FCR), and mortality, were evaluated over the experimental period. Data collected on growth performance were analyzed using factorial ANOVA with Duncan's Multiple Range Test at $P < 0.05$. Breed significantly influenced final body weight (FBW) and total weight gain (TWG), with Red Sokoto goats exhibiting superior performance compared to West African Dwarf goats. Diet significantly affected total feed intake (TFI), daily feed intake (DFI), and FCR, with goats fed 100% DS consuming more feed, while 50%DS+50%CH produced the most efficient FCR. Sex significantly influenced FBW, TWG, and daily weight gain (DWG), with females outperforming males. Significant breed x diet x sex interactions were observed for FBW, TWG, and DWG, with Red Sokoto females fed 50%DS+50% CH showing the highest growth performance. The growth performance in Nigerian indigenous goats is influenced by synergistic interactions among genetic, nutritional, and physiological factors. Within the scope of this baseline study, Red Sokoto females fed a 50%DS+50%CH diet showed promising phenotypic growth response, suggesting this combination warrants further multi-location farm trials for optimized tropical production.

Keywords: Indigenous goats, growth performance, factorial design, feed efficiency, tropical livestock production

Introduction

Goats are vital to Nigeria's livestock sector, providing meat, milk, and income for smallholder farmers under tropical conditions. Nigeria hosts over 70 million goats, predominantly indigenous breeds that constitute more than 90% of the national flock (Kennedy et al., 2025). While these goats are highly resilient to tropical stressors like heat, diseases, and poor-quality forage, they often exhibit suboptimal growth compared to exotic breeds due to genetic limitations and suboptimal management (Salako, 2004). Nigerian indigenous genotypes -such as West African Dwarf (WAD), Red Sokoto (RS), and Sahel thrive across diverse agro-ecological zones, supporting rural economies despite challenges from seasonal feed scarcity and limited breeding structures. Growth performance metrics, including average daily gain and feed conversion ratio (FCR), vary widely based on individual genetic and nutritional management (Akintunde et al., 2025). Despite extensive studies on individual factors, comprehensive research on the combined influence of breed, diet, and sex on growth performance remains scarce, particularly under Nigerian tropical

conditions. Sex dimorphism in growth is noted, with intact males surpassing females, but interactions with breed-specific diets are underexplored (Yakubu et al., 2010). Few studies integrate breed, diet, and sex effects on growth in these goats under tropical conditions. While breed differences exist who reported that Red Sokoto outperforming others in some trials, interactions with diets like forage-based vs. supplemented feeds remain underexplored. Genomic and nutritional research highlights genetic potential but lacks field-specific data on sex dimorphism in growth under Nigeria's climate (Mallam et al., 2025). This study addresses these gaps by evaluating interactions in a controlled tropical setting, filling a critical void in data for breed improvement programs.

Quantifying breed-diet-sex synergies will enable targeted interventions, such as breed selection for specific diets, enhancing average daily weight gain by up to 25% and reducing FCR. This aligns with national policies on genetic resource conservation and climate-resilient agriculture (FMARD, 2017). Economically, improved growth translates to higher off-take rates and incomes for smallholders in northern and southern Nigeria, supporting poverty alleviation. Findings in this study will guide farmers, enhance meat yield, and support breeding programs, boosting livelihoods in tropical smallholdings. Therefore, the aim of this study is to determine the influence of breed (WAD and RS), diet, and sex on growth performance under tropical conditions.

Materials and Methods

The study area

This experiment was carried out at the Livestock Teaching and Research Farm of the Animal Science Department, Faculty of Agriculture, Shabu-Lafia Campus, Nasarawa State University, Keffi. Lafia is located on latitude 08° 35" and longitude 08° 33" (Ovimaps, 2023). It is geographically located in the Guinea Savanna Zone of North Central Nigeria. It has mean maximum monthly temperature of 35.06 °C and mean minimum monthly temperature of 20.16 °C with a mean monthly relative humidity of 74% and the annual rainfall is about 168.90 mm (NiMet, 2023).

Sources of experimental materials

The grass (*Digitaria smutsii*) was sourced from the National Animal Production Research Institute (NAPRI)/Ahmadu Bello University, Shika, Zaria, Nigeria while the two legumes (groundnut haulms and cowpea husk) were sourced from farms after harvest in Lafia, Nasarawa State. After collection, the haulms were brought to the Faculty Livestock Farm, where they were shade-dried and debris was removed before being fed to the experimental goats.

Experimental diets

The diet groups included 100% *Digitaria smutsii*, 50% *Digitaria smutsii* +50% groundnut haulms and 50% *Digitaria* + 50% cowpea husk.

Experimental design, animal allocation and replication

A total of 36 weaner goats were assigned to a 2 x 3 x 2 factorial arrangement within a Completely Randomized Design (CRD), which yields 12 distinct treatment combinations. Each treatment combination was replicated 3 times (12 x 3 = 36 animals in total). To ensure statistical integrity, the 3 replicates per treatment combination were physically managed in separate, individual pens (each pen housing 2 goats of the same breed, diet, and sex combination, serving as the experimental unit). Because body weight and weight gains were recorded dynamically on a weekly basis, the statistical analysis evaluated the overall cumulative growth performance at the end of the trial rather than as repeated measures over time, thereby satisfying the independence assumptions of the fixed-effect factorial ANOVA model.

Experimental goats and management

Physically sound goats were randomly sourced from reputable local farms in Lafia, Nasarawa State, Nigeria. A total of 36 weaner goats of two breeds (West African dwarf, n=18; 9 males + 9 females) and Red Sokoto goats, n=18; 9 males + 9 females) of about 3-4 months of age were sourced for the experiment. Upon arrival, the experimental goats were allowed to acclimatize for a period of 2 weeks during which they were dewormed against endo-parasites and vaccinated against *Peste des petits ruminants* (PPR). The initial body weights were taken and the animals were randomly allotted into the different groups with equal sex

and the weights were balanced with no differences in the initial weights across the groups and diets as well as water were given *ad-libitum*. The feeding trial lasted for a duration of 10 weeks (70 days), which was preceded by the 2-week acclimatization period. Growth performance parameters, including body weight and feed leftovers, were monitored continuously: feed intake was recorded daily, while individual live body weights were recorded weekly to track growth progression. Management practices such as maintain dry, well-ventilated housing to protect the goats from harsh weather and to promote good air quality, regular inspections of the pens, troughs, drinkers, conduct daily cleaning of living areas to reduce odours and prevent disease build-up were done throughout the experimental period (Timveh et al., 2022).

Proximate analysis of the experimental materials

The chemical and nutrient compositions of the experimental components (*Digitaria smutsii*, groundnut haulms, and cowpea husk) were analyzed at the Biochemistry Laboratory, National Animal Production Research Institute (NAPRI)/Ahmadu Bello University, Zaria, is presented in Table 1. Nigeria using the methods proposed by Association of Official Agricultural Chemists (2008) for the determination of their nutrients' composition.

Table 1: Chemical and nutrient compositions of the experimental materials

Experimental materials	%DM	%Ash	%EE	%CF	%CP	%NDF	%ADF
DS	94.08	6.76	1.10	34.08	13.06	63.46	34.67
GH	92.16	8.38	6.71	20.94	25.19	38.09	31.18
CH	93.88	6.36	19.18	25.50	23.13	36.92	15.89

DS= *Digitaria smutsii*, GH= Groundnut haulm, CH= Cowpea husk, DM= Dry matter, EE= Ether extract, CF= Crude fibre, CP= Crude protein, NDF= Neutral detergent fibre, ADF= Acid detergent fibre.

Feed intake, body weight and weight gain

Diets and clean drinking water were offered *ad-libitum* daily at 08:00 h. Feed intake was determined daily by subtracting the weight of the morning leftovers from the total feed offered the previous day using a Mettler Toledo 0.001g precision laboratory analytical electronic balance digital sensitive weighing scale. Body weight (BW) was taken using industrial hook hanging weight Crane scale to the nearest 0.1kg. The goats were flipped upside down inside a Hessian Jute bag/sack, and their weight was measured by subtracting the bag/sack's weight from the total weight. Data on body weights were taken on a weekly basis. Weight gain (final weight – initial weight at every week) was calculated.

Diets and clean drinking water were offered *ad-libitum* daily at 08:00 h. Feed intake was determined daily by subtracting the weight of the morning leftovers from the total feed offered the previous day using a high-precision electronic balance."

Feed conversion ratio

The feed conversion ratio (FCR) was calculated as:

$$\text{Feedconversionratio} = \frac{\text{Feedintake}}{\text{Bodyweightgain}}$$

Mortality: Mortality during the study was recorded as they occurred and was expressed in percentage and calculated as:

$$\text{Mortality} = \frac{\text{Numberofdeadgoats}}{\text{Numberofgoatshoused}} \times 100$$

Statistical analysis, model assumptions, and post-hoc tests

Data collected on growth performance were analysed using factorial Analysis of Variance (ANOVA) to test the fixed effect of breed, diet and sex as well as their interactions in Statistix Analytical software, file version 8.0. Prior to running the final variance analysis, data were verified for normality using the Shapiro-Wilk test and homogeneity of variances using Levene's test. All percentage data (mortality) were transformed using arcsine square-root transformation in radians before analysis to meet ANOVA assumptions. Main effects and all two-way and three-way interaction margins were computed. Duncan's Multiple Range Test was applied as the post-hoc strategy for mean separations only when the F-test for an effect or interaction was significant at $P < 0.05$.

The mathematical model employed was:

$$Y_{ijkl} = \mu + B_i + D_j + S_k + (BD)_{ij} + (BS)_{ik} + (DS)_{jk} + (BDS)_{ijk} + e_{ijkl}$$

Where;

Y_{ijkl} = observation

μ = overall mean

B_i = effect of breed

D_j = effect of diet

S_k = effect of sex

$(BD)_{ij}$, $(BS)_{ik}$, $(DS)_{jk}$, $(BDS)_{ijk}$ = interaction effects

e_{ijkl} = random error

Results and Discussion

Effect of breed on growth performance of experimental goats is presented in Table 2. The results indicated significant ($P < 0.05$) difference in final body weight (FBW) and total weight gain (TWG) with Red Sokoto breed having significantly ($P < 0.05$) higher FBW and TWG compared to West African Dwarf (WAD) breed. Meanwhile, the results obtained revealed that breed had no significant ($P > 0.05$) effect on daily weight gain (DWG), total feed intake (TFI), daily feed intake (DFI), feed conversion ratio (FCR) and mortality (MT).

The differences observed between Red Sokoto (RS) and West African Dwarf (WAD) goats agree with the findings of Nwachukwu et al. (2012) who reported higher body weight and daily weight gain in RS goats and its crosses with the WAD goats. The differences in body weight and daily gain of the animals were similar to the findings of Hassen and Fuerst-Waltl (2004). The possible reason for improved outcomes in Red Sokoto goats might stem from the practice of selectively breeding them over many generations to develop characteristics like quicker development, increased body mass, and improved efficiency in converting feed into body weight. These selective breeding practices have likely resulted in genetic differences between Red Sokoto and WAD goats, favouring better performance in Red Sokoto goats. The no significant differences in the FCR in the current study is at variance with the report of Nwachukwu *et al.* (2012) who reported significant differences between RS and WAD for FCR with WAD breed having the best FCR.

Table 2: Effect of breed on growth performance of experimental goats

Parameters	Breed		P-value
	WAD	RS	
IBW (kg)	5.16±0.08	5.34±0.09	0.2232
FBW (kg)	8.26±0.38 ^b	9.23±0.41 ^a	0.0270
TWG (kg)	3.10±0.17 ^b	3.89±0.01 ^a	0.0104
DWG (kg)	0.05±0.01	0.06±0.01	0.5734
TFI (kg)	17.12±1.36	15.45±1.34	0.2288
DFI (kg)	0.29±0.02	0.26±0.01	0.2288
FCR	5.80±0.06	4.33±0.57	0.0648
MT (Radians)	0.52±0.02	0.55±0.02	0.1639

^{ab} Means in the same row with different superscripts differ significantly ($P < 0.05$), WAD= West African Dwarf, RS= Red Sokoto, IBW= Initial body weight, FBW= Final body weight, TWG= Total weight gain, DWG=Daily weight gain, TFI= Total feed intake, DFI= Daily feed intake, FCR= Feed conversion ratio, MT= Mortality.

Table 3 presents the effect of diet on the growth performance of experimental goats. The results show no significant ($P > 0.05$) effect in all the parameters except on total feed intake (TFI), daily feed intake (DFI) and feed conversion ratio (FCR). The goats fed 100% DS had significant ($P < 0.05$) effect on TFI and DFI compared to those fed 50%DS+50%GH as well as those fed 50%DS+50%CH.

The no differences observed in the present study for body weight, total weight gain and daily weight gain disagrees with the report of Tekle and Gebru (2018) who observed differences in performance between

Abergelle goats fed 50%DS+50CH, 50%DS+50GH and those fed 100% grass. The observation in this study in terms of higher total and daily feed intake in those fed 100% DS implies that the nutritional composition of the feed can influence the feeding behaviour and nutrient utilization in ruminants. This means that the grass may lack certain essential nutrients or may not be as easily digestible as cowpea husk and groundnut haulms supplemented. Legume supplementation (CH and GH) provides superior nutrient density and organic matter digestibility (OMD > 65%) compared to 100% DS grass (NDF > 65%). This higher nutritional value induces rapid metabolic satiety, decreasing total dry matter intake while simultaneously optimizing feed conversion efficiency via enhanced volatile fatty acid production. This could mean that the goats can extract more nutrients from those supplemented with groundnut haulms and cowpea husk, leading to a decreased need for large quantities of feed. Legume supplements like CH and GH increase microbial protein synthesis and volatile fatty acid (VFA) production, enhancing energy utilization efficiency and reducing the need for excessive intake. Goats on 100% DS likely experienced slower fiber degradation (NDF > 65%), prolonging rumen retention and hunger signals, whereas supplemented diets improved organic matter digestibility (OMD > 65% vs. <55%), extracting more net energy per unit feed. Despite this, the lack of BW/TWG/DWG responses suggests that intake compensation in DS-fed goats-maintained growth parity, possibly due to breed resilience under tropical conditions or trial duration limitations.

Table 3: Effect of diet on the growth performance of experimental goats

Parameters	Diets			P-value
	100%DS	50%DS+50%GH	50%DS+50%CH	
IBW (kg)	5.27±0.11	5.35±0.09	5.13±0.13	0.4500
FBW (kg)	8.39±0.47	8.69±0.51	8.74±0.47	0.7172
TWG (kg)	3.12±0.57	3.34±0.57	3.61±0.58	0.839
DWG (kg)	0.05±0.01	0.06±0.01	0.06±0.01	0.7865
TFI (kg)	25.98±1.67 ^a	12.82±1.17 ^b	10.04±1.16 ^c	0.0000
DFI (kg)	0.43±0.03 ^a	0.21±0.01 ^b	0.17±0.01 ^b	0.0000
FCR	8.60±0.58 ^b	3.50±0.57 ^a	2.83±0.57 ^a	0.0008
MT (Radians)	0.42±0.02	0.46±0.01	0.42±0.02	0.1573

^{ab} Means in the same row with different superscripts differ significantly ($P < 0.05$), DS= *Digitaria smutsii*, GH= Groundnut haulms, CH= Cowpea husk, IBW= initial body weight, FBW= final body weight, TWG= total weight gain, DWG= Daily weight gain, TFI= Total feed intake, DFI= Daily feed intake, FCR= feed conversion ratio, MT= mortality, kg=kilogramme.

Effect of sex on the growth performance of experimental goats is shown in Table 4. The results revealed that sex had significant ($P < 0.05$) effect on all the parameters except on mortality (MT). The results indicated that female goats had significantly ($P < 0.05$) higher final body weight (FBW), total weight gain (TWG) and daily weight gain (DWG) compared to the male goats.

Sex-related differences in growth performance observed in this study align with Aliyu et al. (2021), who documented superior growth traits in male versus female Sahelian goats under semi-arid conditions in Katsina State, Nigeria. Conversely, these findings differ from Shuaibu et al. (2020), who found no significant sex effects on live weight, body length, wither height, loin girth, or ear length in Red Sokoto goats. The unexpected superior growth performance of female goats over males in this specific trial can be attributed to the young physiological stage of the animals (3–4 months old weaners). At this pre-pubertal stage, the pronounced anabolic effects of testosterone in intact males have not yet fully manifested to drive significant muscle accretion over females. Furthermore, under tropical environmental stressors, young females often exhibit higher behavioural resilience and lower maintenance energy requirements compared to intact males, allowing them to channel a greater proportion of available nutrients toward growth. Similar sex-influenced growth variations at early life stages have been reported by Bedada et al. (2019) and Idiong and Udom (2011). Such differences are often linked to androgenic hormones in males, which promote muscle accretion and skeletal growth, as evidenced in morphometric studies of Nigerian indigenous goats (Fajemilehin & Salako, 2008). These results underscore the need to account for sex in multi-factorial designs, particularly when extrapolating to farmer-level production where castration or breeding goals may modulate outcomes.

Table 4: Effect of sex on the growth performance of experimental goats

Parameters	Sex		P-value
	Male	Female	
IBW (kg)	5.30±0.09	5.19±0.08	0.4273
FBW (kg)	7.57±0.39 ^b	9.64±0.41 ^a	0.0114
TWG (kg)	2.27±0. 57 ^b	4.45±0. 58 ^a	0.0458
DWG (kg)	0.04±0.00 ^b	0.07±0.00 ^a	0.0213
MT (Radians)	0.52±0.02	0.56±0.02	0.1639

^{ab} Means in the same row with different superscripts differ significantly ($P < 0.05$), RS= Red Sokoto, IBW= Initial body weight, FBW= Final body weight, TWG= Total weight gain, DWG=Daily weight gain, MT= Mortality, kg= Kilogramme.

Table 5 represents the effect of breed x diet on the growth performance of experimental goats. The results revealed that interaction between breed x diet had no significant ($P>0.05$) effect in all the growth traits except on the total feed intake (TFI), daily feed intake (DFI) and feed conversion ratio (FCR). The WAD x 100%DS had significantly ($P<0.05$) higher TFI and DFI but statistically similar to RS x 100%DS for TFI and DFI, and the least TFI and DFI were found in WAD x 50%DS+50%CH. The best FCR was observed in WAD x 50%DS+50%CH though statistically similar to RS x 50%DS+50%GH and RS x 50%DS+50%CH.

The highest total feed intake (TFI) and daily feed intake (DFI) recorded for West African Dwarf (WAD) goats fed 100% *Digitaria smutsii* (DS) comparable to Red Sokoto (RS) × 100% DS interactions, align with Herdt (1993), who noted that forage-dominant diets enhance rumination, salivation, and rumen dilution, thereby promoting greater voluntary feed consumption. This pattern is further supported by Ribeiro et al. (2009), who demonstrated that feeding level influences intake and selective foraging in feedlot Canindé and Moxotó goats without altering diet composition. Similarly, Barreto et al. (2012) observed breed-specific responses to energy-varying diets, with Canindé goats exhibiting superior intake, digestibility, and weight gain relative to Moxotó goats.

These results highlight the critical interplay of breed genetics and dietary forage proportion in modulating feed intake under tropical systems, informing tailored strategies to balance efficiency and performance in indigenous goat production.

Effect of breed × sex interactions on the growth performance of experimental goats

Effect of breed × sex interactions on the growth performance of experimental goats are shown in Table 6. The obtained results had significant ($P<0.05$) effect in all the parameters except on initial body weight (IBW) and mortality (MT). The interaction revealed that Red Sokoto x female had significantly ($P<0.05$) highest values for final body weight (FBW), total weight gain (TWG) and daily weight gain (DWG) and the least were found in West African Dwarf x male. The breed by sex have no significant ($P>0.05$) effect on the mortality (MT).

The superiority expressed in Red Sokoto x females could be due to the fact that RS and female goats performed better in individual performance and the better performance in the interaction is as a result of their individual outstanding performance in FBW, TWG and DWG. The observed results corroborate the work of Yakubu et al. (2010) where differential analysis of morphometric differentiation in WAD and RS goats revealed that RS goats were superior to WAD goats in body size and skeletal proportions, and there is need for conservation and genetic improvement of these important Nigerian goat breeds. Rotimi et al. (2015) stated that the body mass of goats is influenced by their sex, with females typically having higher values. That means the observed higher performance in the interaction between RS breed and female goats in the present study further confirmed the above. Similarly, Idiong and Udom (2011) reported higher chest girth in female goats and concluded that female goats showed superiority in growth performance and morphometric traits as observed in the current study.

Table 5: Effect of breed × diet on the growth performance of experimental goats

Parameters	WAD			RS			P-value
	100%DS	50%DS+50%GH	50%DS+50%CH	100%DS	50%DS+50%GH	50%DS+50%CH	
IBW (kg)	5.34±0.15	4.92±0.26	5.23±0.12	5.19±0.15	5.48±0.15	5.33±0.15	0.2464
FBW (kg)	8.71±1.22	7.49±0.32	8.47±1.15	8.03±0.47	8.91±0.41	9.45±1.27	0.8264
TWG (kg)	3.37±0.58	2.57±0.57	3.24±0.58	2.84±0.57	3.43±0.58	4.12±0.58	0.5346
DWG (kg)	0.06±0.01	0.04±0.01	0.05±0.01	0.05±0.01	0.06±0.00	0.07±0.00	0.4097
TFI (kg)	28.35±2.37 ^a	14.65±2.17 ^b	8.36±1.56 ^c	23.62±2.35 ^a	10.99±1.54 ^{bc}	11.73±1.66 ^{bc}	0.0433
DFI (kg)	0.47±0.03 ^a	0.24±0.01 ^b	0.14±0.02 ^c	0.39±0.04 ^a	0.18±0.01 ^{bc}	0.21±0.03 ^{bc}	0.0433
FCR	7.83±0.58 ^c	6.00±0.57 ^b	2.80±0.06 ^a	7.80±0.58 ^c	3.00±0.57 ^a	3.00±0.57 ^a	0.0000
MT (Radians)	0.47±0.01	0.49±0.01	0.47±0.01	0.49±0.01	0.51±0.02	0.49±0.02	0.8096

^{abc} Means in the same row with different superscripts differ significantly ($P < 0.05$) WAD= West African Dwarf, RS= Red Sokoto, DS= Digitaria smutsii, GH= Groundnut haulms, CH= Cowpea husk, IBW= initial body weight, FBW= final body weight, TWG= total weight gain, DWG= Daily weight gain, TFI= Total feed intake, DFI= Daily feed intake, FCR= feed conversion ratio, MT= mortality, kg=kilogramme, P-value ≤ 0.05 means there is significant difference while P-value $P > 0.05$ means there is no significant difference.

Table 6: Effect of breed × sex on the growth performance of experimental goats

Parameters	WAD		RS		P-value
	M	F	M	F	
IBW (kg)	5.22±0.12	5.10±0.12	5.39±0.12	5.28±0.12	0.9432
FBW (kg)	7.03±0.56 ^b	9.09±0.50 ^{ab}	8.13±0.50 ^{ab}	10.24±0.65 ^a	0.0110
TWG (kg)	1.81±0.57 ^b	3.99±0.57 ^{ab}	2.74±0.56 ^{ab}	4.96±0.58 ^a	0.0215
DWG (kg)	0.03±0.00 ^c	0.07±0.01 ^{ab}	0.05±0.00 ^{bc}	0.08±0.01 ^a	0.0013
MT (Radians)	0.52±0.02	0.54±0.02	0.54±0.01	0.56±0.02	0.6360

^{abc} Means in the same row with different superscripts differ significantly ($P < 0.05$) WAD= West African Dwarf, RS= Red Sokoto, IBW= initial body weight, FBW= final body weight, TWG= total weight gain, DWG= Daily weight gain, MT= mortality, kg=kilogramme, M= male, F= Female, P-value ≤ 0.05 means there is significant difference while P-value $P > 0.05$ means there is no significant difference.

Effect of diets × sex interactions on the growth performance of experimental goats

Table 7 represents the effect of diets × sex interactions on the growth performance of experimental goats. The observed results showed that the diet x sex had significant ($P < 0.05$) effect on all the parameters except on initial body weight (IBW) and mortality (MT). The 100%DS x female had significantly ($P < 0.05$) higher FBW but statistically similar to 50%DS+50%CH x female while the least was found in 100%DS x male. The 100%DS x female had significant ($P < 0.05$) effect on total weight gain (TWG) and the least value was observed in 100%DS x male. Similar trends were observed in daily weight gain with the highest and least found in 100%DS x female and 100%DS x male, respectively.

The possible reason for observed results could be that female goats may find *Digitaria smutsii* and 50%DS+50%CH more palatable and digestible thereby leading to improved performance compared to male fed 100%DS. The present study is similar with the findings of Ribeiro *et al.* (2009) who reported variation in the interaction among diet and sex and expressed that the observed disparities in final body weight gain, total weight gain, and daily weight gain may be attributed to variations in diet composition and sexual dimorphism. The results of this study further support the report of Bedada *et al.* (2019) who stated that sex × diet had an effect on weight gain in goats (Agaviezor *et al.*, 2012). The dietary differences in final body weight and daily gain are due to the genetic potential of each sex.

Effect of breed × diet × sex on the growth performance of experimental goats is presented in Table 8. The results showed a significant ($P < 0.05$) effect in final body weight (FBW), total weight gain (TWG) and daily weight gain (DWG) with RS x 50%DS+50%CH x female had the highest FBW, TWG and DWG. Meanwhile, the FBW observed in RS x 50%DS+50%CH x female was similar with that obtained in WAD x 100%DS x female, RS x 100DS x female, WAD x 50%DS+50%CH x female and RS x 50%DS+50%CH x male. The observed result revealed that breed by diet by sex have no significant ($P < 0.05$) effect on mortality.

The observed results showed clearly that the best combination is the female Red Sokoto goats fed 50%DS+50%CH. The work agrees with the work of Yashim *et al.* (2016) who stated that Red Sokoto goats fed 40% cowpea had higher body weight than those fed 40% groundnut haulms and the control group fed with *Digitaria smutsii*. The higher body weight in those fed 50%DS+50CH is similar to the report of Idiong and Udom (2011) who stated that diet quality had also been implicated in the performance of goats with diets containing legumes having higher body weight. The differences could be due to the varying proximate compositions of the diets, genetic make-up of Red Sokoto goats and sexual dimorphism with females having higher final weight (Maake *et al.*, 2021). The distinct three-way interaction observed for final body weight, total weight gain, and daily weight gain highlights a vital physiological phenomenon which means sexual dimorphism in tropical goats is not uniform across genotypes and is highly modulated by plane of nutrition. Red Sokoto females possessed the metabolic capacity to efficiently utilize the high crude protein (23.13%) and lower neutral detergent fiber (36.92%) present in the 50%DS+50%CH diet compared to their WAD counterparts. Also, while the three-way interaction statistically favored Red Sokoto females fed the 50% DS + 50% CH diet ($P = 0.0403$), the practical significance lies in the substantial reduction of the feed conversion ratio (FCR) from 8.60 (on 100% grass) down to 2.83 and 3.50 on the legume-supplemented diets. Clinically and economically, this demonstrates that utilizing readily available agricultural by-products like cowpea husk and groundnut haulms drastically improves feed efficiency under tropical conditions, making it a highly practical and low-cost feeding strategy for smallholder farmers, irrespective of minor variations between the animal groups. This implies that legume supplementation provides highly fermentable nitrogen and soluble carbohydrates to the rumen, driving microbial protein synthesis and volatile fatty acid production. This nutritional boost works synergistically with the distinct metabolic and endocrine profiles of the Red Sokoto breed, allowing females of this genotype to express their growth potential more robustly under tropical conditions than when restricted to low-quality, high-fiber 100% DS grass.

Table 7: Effect of diet × sex on the growth performance of experimental goats

Parameters	100%DS		50%DS+50%GH		50%DS+50%CH		P-value
	M	F	M	F	M	F	
IBW (kg)	5.51±0.15	5.02±0.15	5.20±0.13	5.50±0.13	5.20±0.18	5.05±0.19	0.0775
FBW (kg)	7.58±0.76 ^c	9.60±1.06 ^a	7.97±0.75 ^b	7.81±1.51 ^b	7.97±0.75 ^b	9.22±0.62 ^a	0.0380
TWG (kg)	2.07±0.07 ^c	4.58±0.12 ^a	2.77±0.01 ^c	2.31±0.01 ^d	2.77±0.01 ^c	4.17±0.00 ^b	0.0000
DWG (kg)	0.03±0.00 ^b	0.08±0.01 ^a	0.06±0.01 ^{ab}	0.04±0.00 ^{ab}	0.05±0.01 ^{ab}	0.07±0.01 ^{ab}	0.0194
MT(Radians)	0.47±0.01	0.49±0.01	0.49±0.02	0.51±0.02	0.47±0.01	0.49±0.01	0.7156

^{abcde} Means in the same row with different superscripts differ significantly ($P < 0.05$), DS= *Digitaria smutsii*, GH= *Groundnut haulms*, CH= *Cowpea husk*, IBW= initial body weight, FBW= final body weight, TWG= total weight gain, DWG= Daily weight gain, MT= mortality, kg=kilogramme, M= male, F= female, P-value ≤ 0.05 means there is significant difference while P-value $P > 0.05$ means there is no significant difference.

Table 8: Effect of breed × diet × sex interactions on the growth performance of experimental goats

Breed	Diet	Sex	Parameters				
			IBW (kg)	FBW (kg)	TWG (kg)	DWG (kg)	MT (Radians)
WAD	100%DS	M	5.45±0.20	7.48±0.30 ^b	2.03±0.01 ^h	0.03±0.00 ^g	0.49±0.01
	100%DS	F	5.23±0.21	9.94±1.18 ^a	4.71±0.03 ^b	0.08±0.01 ^b	0.50±0.01
RS	100%DS	M	5.57±0.21	7.61±0.68 ^b	2.04±0.01 ^h	0.03±0.00 ^g	0.50±0.01
	100%DS	F	4.82±0.21	9.27±1.18 ^a	4.45±0.00 ^d	0.07±0.00 ^c	0.51±0.01
WAD	50%DS+50%GH	M	5.08±0.16	7.04±0.83 ^b	1.97±0.00 ⁱ	0.03±0.00 ^g	0.50±0.01
	50%DS+50%GH	F	5.37±0.17	7.81±1.18 ^b	2.44±0.00 ^g	0.04±0.00 ^f	0.51±0.01
RS	50%DS+50%GH	M	5.33±0.21	8.91±0.84 ^{ab}	3.58±0.04 ^e	0.06±0.00 ^d	0.51±0.01
	50%DS+50%GH	F	5.64±0.21	8.83±0.71 ^{ab}	3.19±0.03 ^f	0.05±0.00 ^e	0.52±0.02
WAD	50%DS+50%CH	M	5.14±0.37	7.15±1.18 ^b	2.01±0.01 ⁱ	0.03±0.00 ^g	0.49±0.01
	50%DS+50%CH	F	4.70±0.37	9.24±0.68 ^a	4.54±0.03 ^c	0.08±0.01 ^b	0.50±0.00
RS	50%DS+50%CH	M	5.27±0.21	9.98±0.73 ^a	4.71±0.02 ^b	0.08±0.01 ^b	0.51±0.01
	50%DS+50%CH	F	5.40±0.21	10.72±0.84 ^a	5.32±0.01 ^a	0.09±0.01 ^a	0.51±0.01
P-value			0.3248	0.0403	0.0000	0.0000	0.4659

^{abcdeghij} Means in the same column with different superscripts differ significantly ($P < 0.05$) DS= *Digitaria smutsii*, GH= *Groundnut haulms*, CH= *Cowpea husk*, IBW= initial body weight, FBW= final body weight, TWG= total weight gain, DWG= Daily weight gain, MT= mortality rate, kg=kilogramme, M= male, F= Female, P-value ≤ 0.05 means there is significant difference while P-value $P > 0.05$ means there is no significant difference

Conclusion and recommendations

This study demonstrates that growth performance of Nigerian indigenous goats is significantly influenced by breed, diet, sex, and their interactions. Red Sokoto goats exhibited superior final body weight and total weight gain compared to West African Dwarf goats, indicating inherent genetic advantages for growth traits. Although diet did not directly affect body weight gain, it significantly influenced feed intake and feed conversion efficiency, with the 50% DS + 50% CH diet yielding the most favourable FCR. Female goats consistently outperformed males in growth parameters, suggesting physiological and possibly endocrine influences on growth efficiency under tropical conditions. The significant three-way interaction (breed $\times$ diet $\times$ sex) highlights the importance of integrated management strategies rather than isolated factor consideration.

Based on these specific experimental conditions, Red Sokoto goats show strong genetic potential in growth-oriented setups. Supplementation with a 50%DS+50% CH diet provides an efficient feeding template. While female Red Sokoto goats responded optimally to this dietary regime in this study, further long-term research on a larger herd scale is suggested to confirm the economic viability of this specific breed-sex-diet combination for smallholders.

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Ethics

All procedures for this study were approved by the Ethical committee of Department of Animal Science, Nasarawa State University, Nasarawa State, Nigeria

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