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EFFECTS OF FEEDING *PENNISETUM PURPUREUM* SILAGE ON GROWTH PERFORMANCE, DIGESTIBILITY AND NITROGEN METABOLISM OF DWARF GOATS

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ABSTRACT

This study investigates the effect of feeding *Pennisetum purpureum* (Napier grass) silage supplemented with farm residues on growth performance, digestibility and nitrogen metabolism in West-African Dwarf bucks. Sixteen (16) bucks were fed varying levels of Napier grass (100 %, 70 %, 50 % and 30 %) with cassava peel, maize stover, groundnut husk and yam peel as supplementary feeds. The findings reveal that supplementation significantly improved growth rates, feed efficiency and nutrient digestibility. Higher supplementation (T4: 70 % supplement) resulted in the highest weight gain (11.57 kg), improved dry matter and protein digestibility and enhanced nitrogen retention. Napier grass, alone with good and high dry matter and protein content, was insufficient to meet the nutritional needs of the bucks, reinforcing the need for protein and energy-dense supplements. The study shows that strategic supplementation of Napier grass-based diets with locally available farm residues can optimize goat growth and production efficiency. The diets with up to 70 % supplementation are recommended to smallholder farmers to maximize growth, feed efficiency and nitrogen retention, thus contributing to enhanced livestock productivity.

Key words: *Pennisetum purpureum*; West African Dwarf bucks; supplementation; growth performance; nitrogen metabolism; feed efficiency

INTRODUCTION

Goat production is an integral part of Nigeria's mixed crop and livestock production systems. Sheep and goat provide a source of income for resource poor farmers in money, food, fertilizer and fibre. Sheep and goat production belongs to a mixed crop-livestock production system, which is based on communal pastures that are declining due to crop encroachment and canyon erosion (Mengistie, 2008; Adeyemi, 2017). Therefore, an alternative feeding strategy is required that can defuse the problem of livestock feeding. The use of the cut-and-haul system is a key principle for the successful integration of farming and cropping systems to control grazing (Yahya *et al.*, 2023). Napier grass is preferred for its high dry matter content, palatability and suitability for cutting and transportation. Napier grass has an average crude protein value of 5.9 − 13.8 % (Safari *et al.*, 2001; Kiende *et al.*, 2007; Guimarães *et al.*, 2023). There will be a need for an alternative feeding strategy that can alleviate the problem of livestock feeding.

The goals of the study were to determine the effect of *Pennisetum purpureum* silage with selected farm residue on growth rate, body parameters, digestibility and nitrogen metabolism of West African dwarf Buck for fattening.

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MATERIALS AND METHODS

Study location

The experiment was conducted at the Teaching and Research Farm of the Department of Animal Production and Health, Faculty of Agriculture, Federal University Oye-Ekiti, Ekiti State, Nigeria. The location was within longitude of 5.5145°E and latitude of 7.7983°N, at an elevation of 570 meters above sea level. The climate in the study area was typically tropical, with a relative humidity of 57 – 92 % and an average daily temperature of 68 – 90 °F.

Experimental animals

Sixteen (16) West-African Dwarf bucks (WAD) aged 6 – 7 months with a mean live weight of 9.98 ± 0.21 kg were used. The experiment lasted for 90 days, from June to August 2024.

Experimental design

The study used a completely randomized design with four (4) treatments and four (4) replicates making totally sixteen (16) bucks. Each buck was housed individually. Parameters determined included dry matter intake and live weight gain with associated improvements in feed efficiency. The study assessed feed consumption and dietary body weight gain using fresh *Pennisetum purpureum* supplemented with fresh concentrates in five stages (30, 50, 70 and 100 %). All animals were treated for internal parasites with bomectin from AdvoCare Pharmacy store in Nigeria.

The treatment groups were assigned based on the inclusion of different feed compositions involving cassava peel, maize stover, groundnut husk, yam peel and Napier grass (*Pennisetum purpureum*) as the basal diet. The inclusion levels were following:

T1 (Control): 100 % Napier grass
T2: 70 % Napier grass + 30 % supplementary feed
T3: 50 % Napier grass + 50 % supplementary feed
T4: 30 % Napier grass + 70 % supplementary feed

The study measured feed consumption, dietary body weight gain and feed efficiency. Prior to the experiment, all goats were fed Napier grass *ad libitum* supplemented with 1.0 % commercial pellet of local waste for 14 days. The animals had free access to water and mineral lick blocks.

Data collection and analysis

Growth performance and feed intake were estimated as the difference between daily feed offered and residues. Animals were weighed before the experiment and weekly thereafter. Feed samples were analysed for chemical composition. *Pennisetum purpureum* leaves were harvested from pastures daily and air-dried for use the next day. Napier grass (*Pennisetum purpureum*) was harvested daily from established plots at the Teaching and Research Farm. Grass was harvested from four equal plots, each used for 15 consecutive days, ensuring controlled maturity. Re-growth from three previously used plots was used to complete the experiment.

Management of Napier grass

Napier grass (*Pennisetum purpureum*) was harvested daily from established plots at the Teaching and Research Farm of the Department of Animal Production and Health, Faculty of Agriculture, Federal University Oye-Ekiti, Ekiti State, Nigeria. The grass was harvested 45 – 60 days post-previous harvest from four equal plots so, that its maturity was controlled by cutting at different times to obtain similar quality throughout the experimental period. Each plot was used for 15 consecutive days, and re-growth from three of the previously used plots was used again to complete the experiment. The grass was harvested at about 1 m in height, chopped to a size of about 5 cm and ensiled.

Silage making

To ensure consistent feed supply throughout the experiment, silage was made from Napier grass (*Pennisetum purpureum*) harvested from the Teaching and Research Farm. The grass was harvested at a height of approximately 1 m, chopped into pieces about 5 cm long and immediately prepared for ensiling. The steps for silage production are outlined below.

Chopping and pre-treatment

After harvesting, the grass was chopped to a size of about 5 cm to improve compaction and fermentation efficiency during the ensiling process. The chopped material was allowed to wilt for 24 hours to reduce its moisture content ensuring an ideal dry matter level of 30 – 35 %.

Ensiling process

The wilted grass was then packed tightly into airtight plastic silos to minimize oxygen exposure. The silos were lined with polyethylene sheets to enhance sealing and reduce spoilage. After packing, the silos were sealed and stored in a cool and dry place.

Fermentation

The packed grass underwent anaerobic fermentation for a period of 21 – 30 days. This process allowed the lactic acid bacteria to proliferate, lowering the pH and preserving the nutritional quality of the silage.

Quality assessment

The silage was periodically checked for pH levels, aroma and texture to ensure proper fermentation. Good quality silage had a pH about 4.0 – 4.5, a pleasant smell and a firm texture.

Storage and feeding

Once fermentation was complete, the silage was stored and fed to the goats daily, ensuring a steady supply of high-quality feed. The silage was supplemented with the experimental diets (cassava peel, maize stover, groundnut husk and yam peel) according to the designated inclusion levels for each treatment group. This silage-making process helped maintain feed quality and availability, contributing to the overall success of the feeding experiment.

Digestibility trial

A digestibility trial was done to determine how efficiently West African Dwarf (WAD) bucks utilized nutrients from *Pennisetum purpureum* silage supplemented with selected farm residues. The trial was a critical part of evaluating the impact of the dietary treatment on the animals' growth performance, nitrogen metabolism and overall nutrient absorption.

Experimental setup

The WAD bucks were fed a measured amount of *Pennisetum purpureum* silage supplemented with farm residues for a designated period. The feed intake was carefully recorded to ensure accurate tracking of how much feed the animals consumed during the trial.

Faecal collection

Faecal collection harness bags were used to gather faeces from the bucks over several days, allowing for accurate measurement of undigested feed components. The faecal collection took place after an initial adaptation period, during which the bucks became accustomed to the diet.

Feed and faecal analysis

Samples of both the feed and faeces were analysed for their nutrient composition, focusing on key components like crude protein, fibre and dry matter. This allowed researchers to assess how much of each nutrient was digested versus how much was excreted in the faeces.

The analyses were conducted at the Federal University Oye-Ekiti Laboratory, located within the Department of Animal Production and Health. Standard procedures were employed, including the Kjeldahl method for crude protein determination, gravimetric methods for dry matter and organic matter and the Van Soest method for analysing neutral detergent fibre (NDF) and acid detergent fibre (ADF). All procedures adhered to guidelines established by the Association of Official Analytical Chemists (AOAC, 2007) to ensure accuracy and reliability.

Digestibility calculation

The digestibility of the nutrients was calculated using the following formula:

$$\text{Digestibility (\%)} = \frac{\text{Nutrient intake} - \text{Nutrient excreted}}{\text{Nutrient intake}} \times 100$$

This calculation provided a clear percentage indicating how efficiently the WAD bucks digested and absorbed the feed (Aganga *et al.*, 2005).

Table 1. Ingredient composition of the experimental diets (% of total diet) for WAD bucks for fattening

Ingredient (%)	DIET			
	T1 (Control)	T2	T3	T4
Napier Grass (Basal Diet)	100	70	50	30
Cassava Peel	0	7.5	12.5	17.5
Maize Stover	0	7.5	12.5	17.5
Groundnut Husk	0	7.5	12.5	17.5
Yam Peel	0	7.5	12.5	17.5
Total	100	100	100	100

T1 (Control): 100 % Ensiled Napier grass (no supplementation)
T2: 70 % Napier grass + 30 % supplementary feed
T3: 50 % Napier grass + 50 % supplementary feed
T4: 30 % Napier grass + 70 % supplementary feed

Table 2. Chemical composition of Napier grass (*Pennisetum purpureum*)

Nutrient composition (%)	Ensiled Napier Grass
Dry Matter (DM)	35.00
Crude Protein (CP)	8.50
Crude Fibre (CF)	29.00
Ether Extract (EE)	2.80
Ash	10.00
Nitrogen-Free Extract (NFE)	49.70
Metabolizable Energy (ME) (MJ/kg)	9.50

Table 2 shows ensiled Napier grass, also known as elephant grass, serves as a critical roughage source for ruminants. It has a high dry matter content (35.00 %), primarily due to the high moisture content retained during ensiling. The crude protein content (8.50 %) indicates moderate protein availability, suitable for maintenance but insufficient for optimal growth in young or lactating animals without supplementation. The high crude fibre (29.00 %) content supports rumen function, yet its relatively low metabolizable energy (9.50 MJ/kg) and ether extract (2.80 %) make it less energy dense. The ash content (10.00 %) shows that it is a decent source of minerals, but overall, Napier grass alone requires supplementation to meet the nutrient demands of growing or high-producing animals.

Aganga *et al.* (2005) have similarly emphasized the need for protein and energy supplementation when feeding Napier grass, particularly for goats and other small ruminants, as its nutrient composition is better suited for bulk but lacks sufficient concentrated energy and protein.

Dry Matter (DM): The percentage of the feed's weight that remains after removing water content.

Crude Protein (CP): The measure of the total protein content in the feed.

Crude Fibre (CF): The portion of feed that is indigestible plant material, important for ruminant digestion.

Ether Extract (EE): Indicates the fat content of the feed.

Ash: Represents the total mineral content in the feed.

Nitrogen-Free Extract (NFE): A calculated value representing the carbohydrate content available for energy.

Metabolizable Energy (ME): The available energy that the animal can derive from the feed (measured in mega joules per kilogram, MJ/kg).

Rationale for supplementation

The inclusion of agricultural by-products aimed to improve nutrient intake: Supplementing Napier grass with these ingredients was expected to enhance the overall nutrient intake, particularly crude protein and energy. Reduce feeding costs: Utilizing locally available by-products could lower the cost of feed, making goat production more economical. Promote sustainable agriculture: Recycling agricultural wastes contributes to environmental sustainability and efficient resource utilization.

Feeding procedure

The Bucks were fed twice daily at 08:00 and 16:00 hours. The total daily feed allowance was calculated based on 5 % of the animal's body weight on a dry matter basis. Feed intake was monitored daily by weighing the offered feed and the leftovers the following morning. Water and mineral lick blocks were provided *ad libitum* to ensure adequate hydration and mineral intake.

Statistical analysis

Feed samples were analysed for chemical composition. For statistical analysis, ANOVA SAS version 9.1. model procedure of SAS (SAS 9.1) was used. The model used for the analysis of growth and feed intake is:

$Y_{ij} = \mu + T_i + e_{ij}$,

where:

Y_{ijk} = The observation on growth and feed intake; μ = Overall mean T_i = The fixed effect of treatment and e_{ij} = effect of random error.

RESULTS

The chemical composition of the feed ingredients indicates significant differences ($p < 0.05$) across parameters like dry matter, crude protein, and fibre content. Ensiled Napier grass has lower dry matter content but higher crude fibre compared to cassava peel and maize stover. Groundnut husk stands out for its high fibre and crude protein content. The variability in metabolizable energy and protein values across the feedstuffs demonstrates the potential for different dietary impacts on animal performance when using these ingredients. The results indicate the importance of formulating diets based on the specific nutrient content of each ingredient.

Table 3. Chemical composition of selected feed ingredients fed to WAD bucks for fattening (n = 16 bucks)

Nutrient composition (%)	Ensiled Napier Grass	Cassava Peel	Maize Stover	Groundnut Husk	Yam Peel	SEM
Dry Matter (DM)	35.00	86.50	90.00	88.00	87.50	1.75
Crude Protein (CP)	8.50	3.60	3.10	12.50	4.00	0.90
Crude Fibre (CF)	29.00	13.50	32.00	45.00	20.00	1.60
Ether Extract (EE)	2.80	1.20	1.00	5.50	1.10	0.35
Ash	10.00	7.50	7.00	6.00	5.50	0.40
Nitrogen-Free Extract (NFE)	49.70	74.20	56.90	31.00	69.40	1.10
Metabolizable Energy (MJ/kg)	9.50	13.20	10.00	7.80	11.00	0.50

n = numbers of animal used

Table 4. Growth performance of WAD bucks fed ensiled *Pennisetum purpureum* Grass supplemented with some selected crop residue (n = 16 bucks)

Parameters	Diets				
N = 16 bucks	T1 (Control)	T2	T3	T4	SEM
Average Initial Weight (kg)	7.0	7.1	7.0	7.1	0.10
Average Final Weight (kg)	11.0^{a}	11.25^{ab}	11.40^{ab}	11.57^{b}	0.15
Average Weight Gain (kg/week)	0.50^{a}	0.53^{a}	0.55^{ab}	0.58^{b}	0.02
Average Weekly Gain (g/day)	71.43^{a}	75.71^{a}	78.57^{b}	82.86^{b}	3.10
Average Daily Gain (g/day)	71.43^{a}	75.71^{a}	78.57^{b}	82.86^{b}	3.10
Average Feed Intake (g/day)	650^{a}	620^{a}	580^{b}	540^{b}	25.50
Overall Feed Intake (kg)	45.50^{a}	43.40^{a}	40.60^{b}	37.80^{b}	1.20
Average Dry Matter Intake (g/day)	500^{a}	470^{a}	440^{b}	410^{b}	20.60
Feed Intake as % of Body Weight	4.00^{a}	3.80^{a}	3.60^{b}	3.40^{b}	0.18
DM Intake as % of Body Weight	3.10^{a}	2.90^{a}	2.70^{b}	2.50^{b}	0.15
Feed Gain Ratio	9.10^{a}	8.19^{ab}	7.38^{b}	6.51^{c}	0.50

^{a,b}Values with different superscripts within the same column are significantly different ($P < 0.05$); Values with different superscripts vary significantly; SEM: Standard Error Mean; N = number of animal used.
T1 (Control): 100 % Ensiled Napier grass (no supplementation)
T2: 70 % Napier grass + 30 % supplementary feed
T3: 50 % Napier grass + 50 % supplementary feed
T4: 30 % Napier grass + 70 % supplementary feed

At the end of the experimental period, goats in T4 (30 % Napier + 70 % Supplement) had the highest final weight (11.57 kg) and weight gain per week (0.58 kg/week), showing that a higher level of supplementation improved growth performance. T4 was significantly different from the control group (T1) and T2, indicating that more supplementation led to better growth outcomes. Average daily gain (g/day) followed a similar pattern, with T4 goats growing the fastest at 82.86 g/day, followed by T3, T2, and T1. The values show significant differences between T1 (control) and T4, highlighting the positive impact of supplementation. Interestingly, feed intake decreased as supplementation increased. T1 goats had the highest feed intake (650 g/day), while T4 goats consumed the least (540 g/day). This suggests that goats on higher supplementation diets consumed less feed but gained more weight, indicating improved feed efficiency. The feed gain ratio, which measures the efficiency of feed conversion, was significantly lower in T4 (6.51), indicating the most efficient use of feed. T1 had the highest ratio (9.10), meaning goats required more feed to gain weight

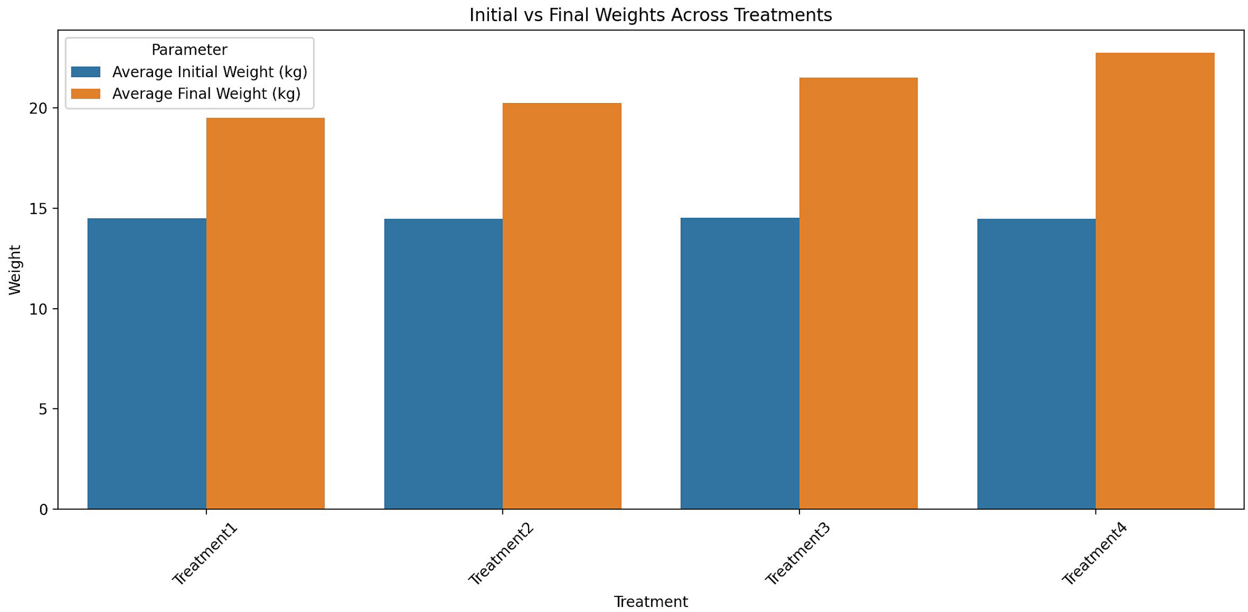

Figure 1. Bar chart (initial vs final weights) shows the progression of weight gain across treatments

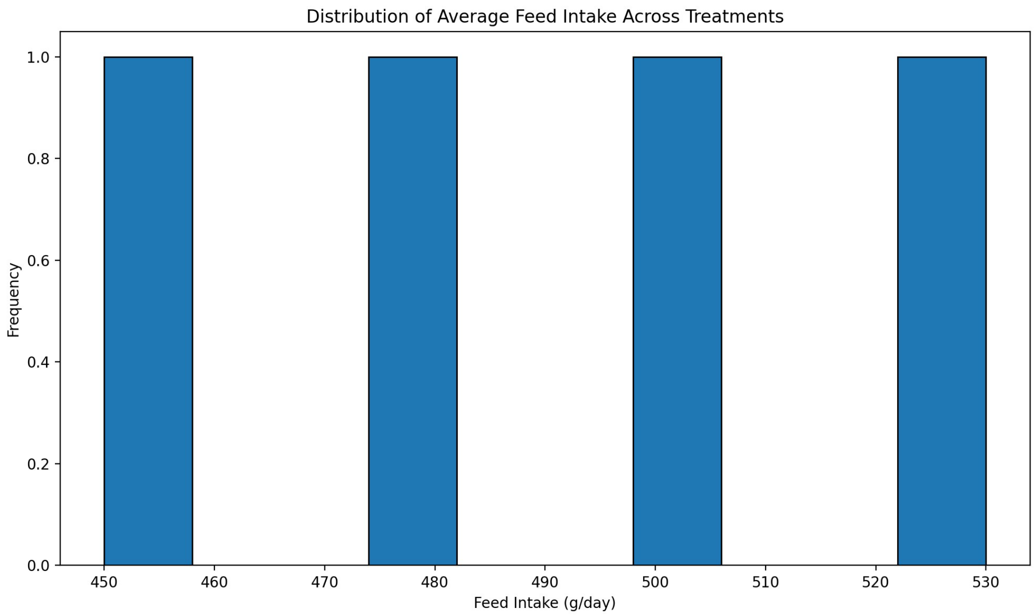

Figure 2. Histogram feed intake distribution shows the distribution of average feed intake across treatments

in the control group. Similarly, dry matter intake as a percentage of body weight was lower for T4 goats (2.50 %) compared to T1 (3.10 %), further indicating that supplementation enhanced the efficiency of nutrient use, as less feed was needed for growth. No mortality was recorded.

Table 5. Digestibility study of WAD buck fed ensiled *Pennisetum purpureum* supplemented with some selected crop residue (n = 16 bucks)

Parameters N = 16 bucks	T1 (Control)	T2	T3	T4	SEM
Dry matter intake (g/day)	500^{a}	470^{ab}	440^{b}	410^{b}	25.50
Dry matter digestibility (%)	70.50^{c}	72.10^{c}	74.50^{ab}	76.20^{a}	1.10
Crude protein intake (g/day)	110^{c}	120^{bc}	130^{ab}	140^{a}	5.20
Crude protein digestibility (%)	64.00^{c}	66.00^{bc}	68.50^{ab}	71.00^{a}	1.90
Neutral detergent fibre digestibility (%)	55.20^{c}	57.30^{c}	60.00^{ab}	62.50^{c}	1.50
Acid detergent fibre digestibility (%)	50.00^{c}	52.10^{c}	55.00^{ab}	58.00^{a}	2.00

^{a,b}Values with different superscripts within the same column are significantly different (P < 0.05); Values with different superscripts vary significantly; SEM: Standard Error Mean; N = number of animal used.
T1 (Control): 100 % Ensiled Napier grass (no supplementation)
T2: 70 % Napier grass + 30 % supplementary feed
T3: 50 % Napier grass + 50 % supplementary feed
T4: 30 % Napier grass + 70 % supplementary feed

Table 6. Nitrogen balance of WAD buck fed ensiled *Pennisetum purpureum* supplemented with some selected crop residue (n = 16 bucks)

Parameters N = 16 bucks	T1 (Control)	T2	T3	T4	SEM
Nitrogen intake (g/day)	17.60^{c}	19.20^{c}	20.80^{ab}	22.40^{a}	1.30
Fecal nitrogen output (g/day)	8.10	8.40	8.80	9.00	0.25
Urinary nitrogen output (g/day)	4.00	3.90	3.70	3.50	0.20
Nitrogen retained (g/day)	5.50^{c}	6.90^{bc}	8.30^{ab}	9.90^{a}	0.50
Nitrogen balance (g/day)	5.50^{c}	6.90^{bc}	8.30^{ab}	9.90^{a}	0.30

^{a,b}Values with different superscripts within the same column are significantly different (P < 0.05); Values with different superscripts vary significantly; SEM: Standard Error Mean; N = number of animal used.
T1 (Control): 100 % Ensiled Napier grass (no supplementation)
T2: 70 % Napier grass + 30 % supplementary feed
T3: 50 % Napier grass + 50 % supplementary feed
T4: 30 % Napier grass + 70 % supplementary feed

Bucks in T1 (Control) had the highest DMI (500 g/day), while those in T4 (30 % Napier + 70 % Supplement) had the lowest (410 g/day). Despite lower intake, T4 Bucks exhibited the highest dry matter digestibility (76.20 %), significantly different from T1, where digestibility was lowest (70.50 %). This indicates that with higher supplementation, the goats utilized the feed more efficiently. Crude protein intake increased progressively from T1 to T4, with T4 having the highest at 140 g/day. Similarly, crude protein digestibility improved significantly from 64.00 % in T1 to 71.00 % in T4. This shows that higher supplementation enhances protein utilization, which is critical for muscle growth and other metabolic functions. Digestibility of NDF and ADF (components related to fibre) also improved with increased supplementation. T1 had the lowest NDF digestibility (55.20 %) compared to T4 (62.50 %). ADF digestibility followed the same trend, rising from 50.00 % in T1 to 58.00 % in T4. This indicates that higher levels of supplementation improve the goats' ability to break down fibrous components of the feed. Nitrogen intake increased from T1 (17.60 g/day) to T4 (22.40 g/day), while nitrogen retained also showed a notable increase from 9.50 g/day in T1 to 13.40 g/day in T4. The nitrogen balance remained positive across all treatments but

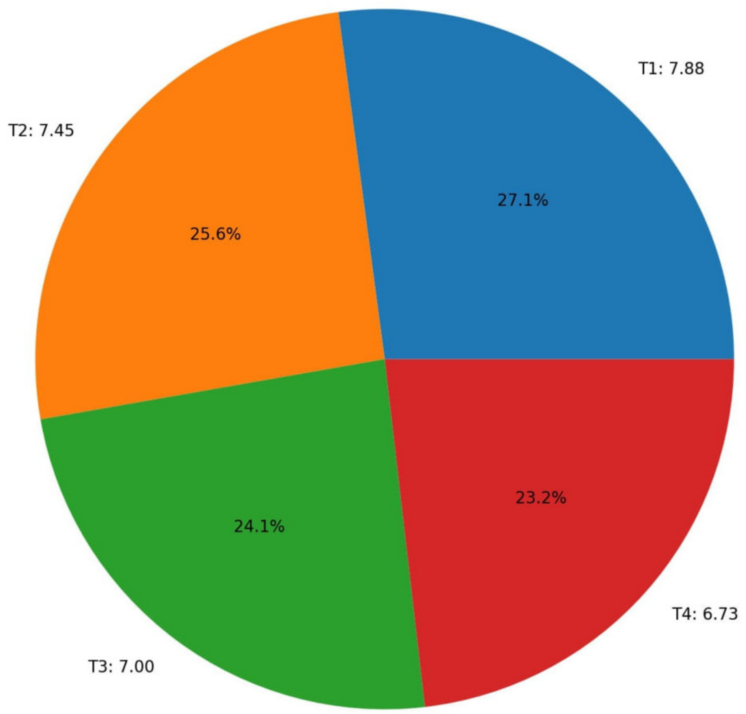

Figure 3. Pie chart of feed gain ratio illustrates the proportion of feed gain ratios across treatments

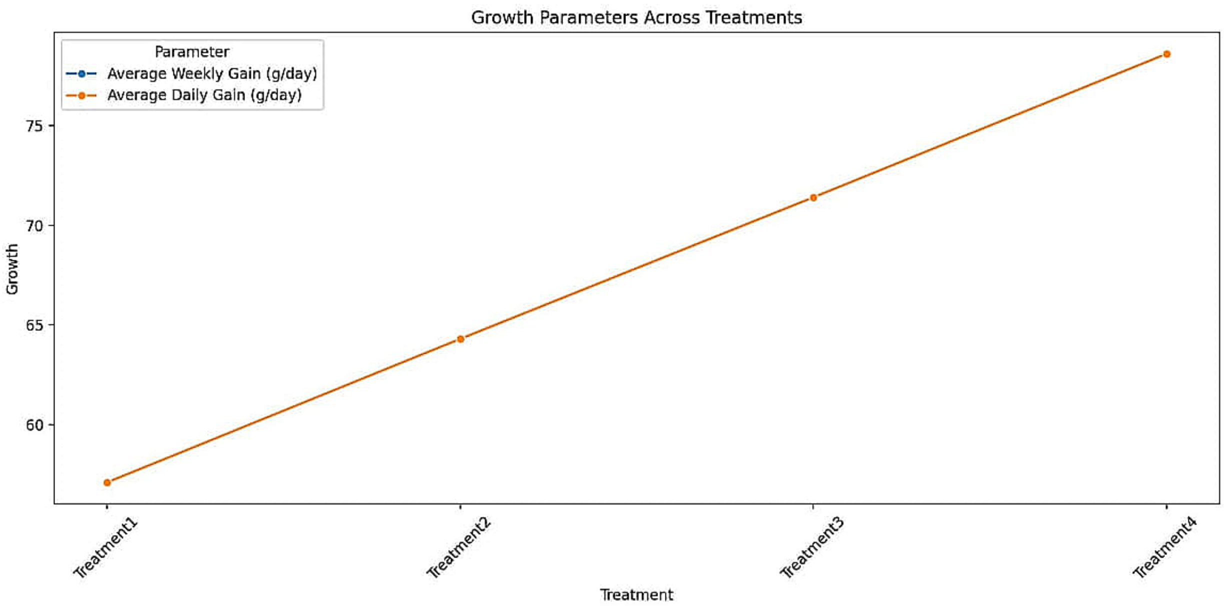

Figure 4. Growth parameters curve

showed incremental improvements with increased supplementation, indicating more nitrogen retention for growth and body functions.

DISCUSSION

Table 3 highlights the nutrient composition of the feed ingredients used in the study, including ensiled Napier grass, cassava peel, maize stover, groundnut husk, and yam peel. The significant differences in nutrient profiles across these feed components demonstrate their distinct contributions to the overall diet. These variations are essential in formulating balanced diets for West African Dwarf goats, as the nutrient content directly influences the animals' growth performance, feed efficiency, and overall health. Ensiled Napier grass had the lowest dry matter content (35.00 %) compared to the supplementary feeds, which had DM values exceeding 86 %. This high moisture content in Napier grass reflects the ensiling process, which preserves forage with a high-water content, making it a good source of roughage for ruminants. However, the low DM content also implies that Napier grass alone cannot meet the nutrient requirements of growing goats, as it contains less concentrated nutrients than the drier supplements like cassava peel and maize stover. Aganga *et al.* (2005) and Oluwadele *et al.*, (2024b) noted that Napier grass is valuable for its fibre content and bulk in ruminant diets, but its lower DM value limits its ability to fully meet energy and protein needs. Therefore, the supplementation with drier, more nutrient-dense feedstuffs become critical. The higher DM content of cassava peel, maize stover, and yam peel enhances the overall nutrient density of the diet, ensuring that goats receive sufficient dry matter intake, which is vital for optimal rumen function and digestion. Crude protein is a critical component of any diet for growing ruminants, as it supports muscle development, repair, and overall growth. Groundnut husk had the highest crude protein content (12.50 %), making it an essential protein source in the diet. Napier grass, although high in fibre, had a moderate protein content of 8.50 %, which is insufficient as a sole source of protein, particularly for growing animals. According to Adedokun *et al.* (2017) and Oluwadele *et al.*, (2023), supplementation with protein-rich feed is necessary to meet the protein requirements of West African Dwarf goats, as low-protein diets can limit growth and productivity. The relatively low crude protein content of cassava peel (3.60 %) and maize stover (3.10 %) further underscores the need for including high-protein supplements like groundnut husk. Islam *et al.* (2023) and Oluwadele et al (2024b) also emphasized that while Napier grass provides roughage, it should be supplemented with protein-dense feeds for optimal animal growth. Crude fibre, an essential component for maintaining rumen function, varied significantly across the ingredients. Groundnut husk had the highest fibre content (45.00 %), followed by maize stover (32.00 %) and Napier grass (29.00 %). Fibre is critical for ruminant diets, as it promotes chewing, salivation, and proper rumen fermentation. However, excessive fibre without adequate energy can limit growth by reducing the availability of digestible nutrients. Oluwadele *et al.* (2024a) noted that while fibre is necessary for maintaining rumen health, diets overly rich in fibre can reduce nutrient absorption and energy intake, slowing down growth. This explains why high-fibre feeds like groundnut husk need to be balanced with energy-rich supplements like cassava peel and yam peel, which provide lower fibre but higher NFE and ME. The EE, representing the fat content of the feed, was highest in groundnut husk (5.50 %), making it a good source of lipids, which provide additional energy. Lipids are important for energy-dense diets, particularly for growing goats that require energy for growth and reproduction. However, the ether extract values for cassava peel, maize stover, and yam peel were relatively low (below 1.20 %), meaning they primarily serve as carbohydrate and fibre sources rather than fat sources. Adeloye and Famakinwa (2014) and Oluwadele *et al*. (2023) suggested that while lipids are crucial for energy, ruminants typically thrive on diets that are high in carbohydrates, like those provided by cassava peel and yam peel, rather than high-fat diets. Therefore, the low EE content in these supplements complements the fibre-rich feeds by providing energy without overwhelming the diet with fat, which can negatively affect rumen fermentation. The ash content of feed indicates the total mineral content, which is essential for metabolic functions such as enzyme activation, bone formation, and fluid balance. Ensiled Napier grass had the highest ash content (10.00 %), indicating a relatively higher mineral concentration compared to the supplements, which had ash content ranging from 5.50 % to 7.50 %. This highlights the importance of Napier grass as a mineral source in the diet (Tawose *et al.*, 2022). Islam *et al.* (2023) stressed the importance of mineral content in forage for supporting metabolic functions and improving animal health. While supplements provide the necessary protein and energy, minerals from Napier grass or other forages ensure that the goats meet their micronutrient requirements, preventing deficiencies that could impair growth and health. NFE represents the readily available carbohydrates in the feed, which provide quick energy to the animals. Cassava peel had the highest NFE (74.20 %), followed by yam peel (69.40 %), making them excellent sources of energy. In contrast, groundnut husk, with a lower NFE (31.00 %), provides more fibre and protein rather than carbohydrates. The ME values further reinforce the role of cassava peel and yam peel as energy supplements, with ME values of 13.20 MJ/kg and 11.00 MJ/kg, respectively. Ensiled Napier grass had a lower ME value (9.50 MJ/kg), emphasizing its role as roughage rather than an energy-dense feed. Adedokun *et al.* (2017) Oluwadele *et al.*, (2023); Oluwadele *et al.*, (2024b) demonstrated that energy-dense supplements improve feed efficiency and growth performance in West African Dwarf goats. This is consistent with the findings in Table 4, where cassava peel and yam peel provide the necessary energy to complement the fibre and protein from Napier grass and groundnut husk. The significant differences ($p < 0.05$) across the feed ingredients in terms of dry matter, crude protein, crude fibre, ether extract, and metabolizable energy underline the importance of selecting feed components based on their nutritional contributions. The results emphasize that no single feed ingredient can meet all the nutritional needs of growing Bucks. A combination of forage and supplements is necessary to ensure that the diet is balanced in terms of energy, protein, fibre, and minerals. According to Tawose *et al.* (2023), balancing the nutrient composition of the diet is critical for maximizing growth, feed efficiency, and overall productivity in West African Dwarf Buck. The significant differences in nutrient content among the ingredients justify the need for strategic supplementation, particularly in small ruminants like goats that are often raised on low-quality forages in many developing countries.

The growth performance data presented in Table 4 and Figure 2, Figure 3 and Figure 4 highlight the impact of varying levels of Napier grass and supplementation on the average weight gain, feed intake, and feed conversion efficiency of West African Dwarf Buck. The Bucks on the highest supplementation level (T4: 30 % Napier + 70 % Supplement) exhibited the highest average weight gain (11.57 kg final weight), suggesting that supplementation enhances growth performance. This finding aligns with the study by Adedokun *et al.* (2017) and Oluwadele *et al.*, (2024b), which demonstrated that the supplementation of West African Dwarf sheep with concentrate feeds improves overall growth, carcass quality, and meat composition. This supports the idea that higher supplementation levels provide more nutrients required for optimal growth, as seen in the increasing daily weight gain from T1 (control) to T4 (82.86 g/day). Feed intake decreased progressively as the proportion of supplementation increased, with T4 (30 % Napier + 70 % Supplement) having the lowest average feed intake (540 g/day). This trend can be attributed to the fact that supplement feeds are more nutrient-dense and thus require less intake to meet the energy requirements of the Bucks, as supported by Adeloye and Famakinwa (2014) and Oluwadele *et al.*, (2023), who found that higher concentrate ratios reduced feed intake in Buck fed a basal diet of forage. Interestingly, despite the lower feed intake in T4, the feed conversion ratio (FCR) improved, with T4 having the best FCR at 6.51. This indicates more efficient conversion of feed into body mass, further demonstrating the positive effect of higher supplementation levels. The control group (T1), with 100 % Napier grass, had the worst FCR (9.10), reinforcing the importance of supplementing low-quality forage like Napier grass with higher energy and protein sources. According to Islam *et al.* (2023), Napier grass, while high-yielding, often requires supplementation for better growth and productivity in livestock due to its relatively low protein content. The significant differences in the average weight gain, feed intake, and feed conversion ratio between the treatments groups can be explained by the nutrient composition of the supplements used. Higher supplementation levels provide more metabolizable energy and protein, which promote growth. As Aganga *et al.* (2005) pointed out, Napier grass alone does not provide sufficient protein to meet the needs of growing animals, especially in its ensiled form. Hence, the inclusion of supplements in the diet of West African Dwarf Buck significantly improves growth performance. Table 5 illustrates the digestibility of DM, CP, NDF, and ADF among goats fed varying ratios of Napier grass and supplements. The results show a clear trend: as supplementation increases, the digestibility of all parameters improves significantly. Buck on the highest supplementation level (T4: 30 % Napier + 70 % Supplement) had the highest dry matter digestibility (76.20 %) and crude protein digestibility (71.00 %), indicating that the nutrient-dense supplements are more easily digestible than Napier grass alone. These results are consistent with the findings of Oluwadele *et al.* (2024a), who observed that supplementation with more digestible feed ingredients improves nutrient absorption in West African Dwarf Buck. The better digestibility in T4 is likely due to the improved quality of the diet with higher levels of supplementation. As AOAC (2007) highlighted, the digestibility of a feed depends on its chemical composition and the balance of nutrients provided. Supplementation with energy and protein-rich feeds typically enhances digestibility by providing nutrients that are easily broken down by the rumen microbes.

The trend in crude protein digestibility is also significant, with goats in T4 showing the highest crude protein digestibility at 71 %. This improvement in protein digestibility is crucial for growth and production in ruminants. Adedokun *et al.* (2017) and Oluwadele *et al.*, (2023) emphasized the importance of protein supplementation for improving growth performance, as protein is essential for muscle development and maintenance. The higher protein intake and digestibility in T4 also support the improved nitrogen balance (presented in Table 5), as more nitrogen is retained in the body for growth and metabolic functions (Kiende *et al.* 2019; Guimaares *et al.* 2023).

NDF and ADF digestibility also increased as supplementation increased. This indicates that higher supplementation helps improve the breakdown of fibre components in the diet, likely due to the improved microbial activity in the rumen. Ekeocha *et al.* (2023) explained that while forage provides fibre essential for proper rumen function, supplementation provides the additional nutrients needed to optimize fibre digestion, leading to better overall nutrient absorption. The nitrogen balance data in Table 6 further supports the findings of the previous tables, showing that higher levels of supplementation improve nitrogen retention and utilization in West African Dwarf goats. Goats in T4 (30 % Napier + 70 % Supplement) had the highest nitrogen intake (22.40 g/day) and nitrogen retention (9.90 g/day), indicating that more nitrogen was available for growth and bodily functions. This aligns with the findings of Tawose *et al.* (2023), who showed that supplementation with cassava peel silage and other high-nitrogen feeds improves nitrogen retention in goats. The significant improvement in nitrogen retention in the T4 group can be attributed to the higher crude protein content in the supplemented feed. Other studies (Aganga *et al.*, 2005; Islam *et al.*, 2023; Oluwadele *et al.*, 2024a; Oluwadele *et al.*, 2024b) emphasized that Napier grass alone does not provide sufficient protein to meet the nitrogen needs of growing animals, especially in its ensiled form. The increased supplementation provides more protein, which is broken down into nitrogenous compounds and absorbed into the bloodstream, resulting in higher nitrogen retention. Faecal nitrogen output was relatively stable across treatments, with a slight increase in T4 (9.00 g/day) compared to T1 (8.10 g/day). This suggests that the higher protein intake in T4 resulted in more nitrogen being excreted in the faeces, a normal occurrence when protein intake exceeds the animals' immediate needs. However, urinary nitrogen output decreased with increasing supplementation, with T4 having the lowest value (3.50 g/day). This indicates that less nitrogen was wasted through urine in the higher supplementation treatments, implying that more nitrogen was utilized for growth and other bodily functions, a pattern noted by Oluwadele *et al.* (2021) in his study on nitrogen utilization in West African Dwarf sheep.

The nitrogen balance, which reflects the difference between nitrogen intake and nitrogen excretion (faecal and urinary), was highest in T4 (9.90 g/day). This positive nitrogen balance indicates that the goats were retaining more nitrogen than they were excreting, which is essential for growth. Adedokun *et al.* (2017) and AOAC (2007) both highlighted the importance of a positive nitrogen balance in growing animals, as it signifies that the animals are synthesizing more protein than they are breaking down, leading to weight gain and improved growth performance. Overall, the results from Table 6 suggest that higher levels of supplementation, particularly with energy- and protein-rich feeds, improve nitrogen retention and utilization in West African Dwarf goats. This leads to better growth performance, as evidenced by the higher weight gain and improved feed efficiency seen in Table 2. This reinforces the need for strategic supplementation in diets based on low-quality forages like Napier grass, as the supplementation provides the necessary nutrients for optimal growth and production in ruminants, as concluded by Oluwadele *et al.* (2023).

CONCLUSION

The study demonstrates that supplementation of West African Dwarf Buck diets with varying proportions of Napier grass and selected local feedstuff significantly impacts growth performance, digestibility, and nitrogen balance. Higher concentrate supplementation improves average daily gain, feed conversion efficiency, and nutrient digestibility, highlighting its importance in enhancing livestock productivity. Optimal supplementation with Napier grass and concentrates can boost smallholder farmers' production efficiency. The findings underline the role of balanced diets in improving goat production outcomes, reducing feed wastage, and maximizing nutrient utilization. This is critical for improving the overall productivity and economic viability of small ruminant farming systems. The study contributes to knowledge by demonstrating that supplementing *Pennisetum purpureum* (Napier grass) silage with farm residues such as cassava peel, maize stover, groundnut husk, and yam peel significantly enhances growth performance, feed efficiency, and nutrient digestibility in West African Dwarf bucks. It provides evidence that higher supplementation levels improve nitrogen retention and utilization, optimizing rumen function and overall productivity. This research offers practical feeding strategies for smallholder farmers, emphasizing the importance of integrating local feed resources to enhance livestock production, which can contribute to improved food security and economic viability.

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ETHICAL APPROVAL

This study was conducted in full compliance with ethical standards for animal research and welfare. All experimental procedures involving animals were approved by the relevant institutional review board and adhered to national guidelines for the ethical treatment of livestock. Care was taken to minimize animal stress and ensure humane handling throughout the study.

AUTHOR'S CONTRIBUTIONS

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All authors have read and agreed to the published version of the manuscript.

DATA AVAILABILITY STATEMENT

The data presented in this study are available on request from the corresponding author.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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