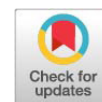


Research Article



Tithonia diversifolia Leaf Meal as a Supplement for West African Dwarf Goats

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Abstract | The study examined the nutritional response and performance of West African Dwarf (WAD) goats fed diets consisting primarily of cassava peel, supplemented with graded levels of *Tithonia diversifolia* leaf meal (TDLM) for 70 days in a feeding trial conducted at the Teaching and Research Farm of Landmark University, Omu Aran, Kwara State, Nigeria. Twenty-four growing WAD goats were randomly assigned to four treatment groups, with six animals in each group. Each treatment was replicated three times, with two animals per replicate. The four experimental diets contained graded amounts of TDLM at 0.00%, 5.00%, 10.00%, and 15.00% levels and were fed at 3% of body weight. The 15% group showed the highest numerical weight gain; however, the differences among treatments were not statistically significant ($p > 0.05$). Nutrient digestibility values for NDF, ADF, and ASH were similar ($p > 0.05$) across dietary treatments. Goats fed diets containing 15% TDLM inclusion levels had significantly ($p < 0.05$) higher crude protein digestibility (73.08%). The feed conversion ratio (FCR) across dietary treatments was similar ($p > 0.05$). However, the lowest FCR (5.32) and the highest weight gain (3.55 kg) were recorded in goats fed 15% TDLM inclusion levels, indicating more efficient utilization of the diets by the goats. The study showed that *Tithonia diversifolia* leaf can be used as a fodder supplement for growing WAD goats up to 15% inclusion in the diet without harmful effects.

Keywords | Alternative feed ingredient, Livestock management, Pelleting, Ruminant nutrition, Sustainable feeding, Sustainable agriculture

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INTRODUCTION

West African Dwarf (WAD) goats are widely reared in Nigeria, particularly by smallholder farmers, due to their adaptability, high demand, and acceptance across the country, as there are no religious restrictions on their consumption (Kolo *et al.*, 2019; Raimi and Adeloye, 2022). They play a vital role in improving household income and addressing animal protein shortage. However, despite their potential, their productivity remains low due to major

challenges, especially high feed costs and inadequate nutrient intake (Olajide *et al.*, 2025). Even with good livestock management practices, natural pastures in Nigeria are often of poor quality and fail to provide sufficient nutrients for optimal animal health and performance (Ajagbe, 2021; Amole *et al.*, 2017). As a result, farmers are forced to rely on low-quality feed resources such as crop residues and household waste, which further limits productivity (Gunun *et al.*, 2024).

Cassava peels, a major by-product of cassava (*Manihot esculenta*) processing, are abundant and readily available in rural areas of Nigeria, making them a promising and cost-effective basal diet for ruminants (Montalvo-González *et al.*, 2021; Olawoye *et al.*, 2020). They are rich in metabolizable energy and have been widely used in feeding various livestock species, particularly in ruminant fattening systems.

However, the use of cassava peels is constrained by their poor nutritional quality, especially their low crude protein content, which limits digestion, nutrient utilization, and overall animal performance when fed alone. This necessitates supplementation to improve their feeding value.

One potential solution is the use of *Tithonia diversifolia* leaves, which are rich in protein, energy, and essential minerals, and have shown promise as a low-cost, nutritionally valuable feed resource (Okeniyi *et al.*, 2025). Incorporating such protein-rich forages into cassava peel-based diets could help address nutrient deficiencies and enhance animal productivity.

Therefore, this study aimed to determine the effect of different inclusion levels of *Tithonia diversifolia* leaves in a pelleted cassava peel-based diet on the nutritional response and performance of growing WAD goats.

MATERIALS AND METHODS

STUDY AREA

This study was carried out in the goat unit of the Teaching and Research Farm of Landmark University, Omu-Aran, Kwara State, Nigeria. Twenty-four growing WAD goats weighing 5.7 ± 0.36 kg and of 5–7 months of age were used. The animals were acclimatized for 2 weeks and treated for ectoparasites and endoparasites before the start of the experiment.

COLLECTION OF *TITHONIA DIVERSIFOLIA* LEAVES, CASSAVA PEEL, AND PROCESSING OF EXPERIMENTAL DIETS

Tithonia diversifolia leaves were harvested from the Landmark University's teaching and research Farm Area. The leaves, including petioles, were harvested, rinsed, and air-dried under the shade for two weeks by spreading them on the concrete floor and turning thoroughly to enhance uniform drying. Fresh cassava peel was collected at the Garri processing unit of Landmark University and sun-dried for one week. After drying, both ingredients were mechanically ground into powder form using a hammer mill grinder. The respective proportion of *Tithonia diversifolia* leaf meal (0%, 5%, 10%, and 15%) was then

incorporated into the four-cassava peel-based diets and mixed thoroughly. After mixing the respective diets, it was mechanically forced through a 6 mm diameter mesh pelleting machine using molasses (5%) as the binding agent to form the four respective experimental diets (Table 1).

Table 1: Feed components of each pelletized diet.

Feed components	T1	T2	T3	T4
Cassava peel	73.00	68.00	63.00	58.00
Maize offal	18.00	18.00	18.00	18.00
Oyster shell	8.00	8.00	8.00	8.00
Salt	0.50	0.50	0.50	0.50
Premix	0.50	0.50	0.50	0.50
<i>Tithonia diversifolia</i> leaf meal	00.00	5.00	10.00	15.00
Total	100.00	100.00	100.00	100.00

EXPERIMENTAL LAYOUT, ANIMALS, AND FEEDING MANAGEMENT

The animals were allocated into four treatments of six animals per treatment and two animals per replicate in a completely randomized design (CRD). The experimental diets were: T1 (Cassava-based diet containing 0% *Tithonia diversifolia* leaf meal), T2 (Cassava-based diet containing 5% *Tithonia diversifolia* leaf meal), T3 (Cassava-based diet containing 10% *Tithonia diversifolia* leaf meal), T4 (Cassava-based diet containing 15% *Tithonia diversifolia* leaf meal). Each group of animals was assigned to an experimental diet and was fed ad libitum, while fresh water was also supplied. Ivermectin (1 mL/50 kg body weight), oxytetracycline (10 mg/kg body weight), and multivitamin (1 mL/10 kg body weight) injectable solution were administered, respectively, against endo and ecto parasites. The pens were also swept daily before feeding the animals.

DATA COLLECTION AND ANALYSIS

A known quantity of feed and water was measured and administered to the animals under each treatment. Leftover feed and water were collected daily; and weighed to estimate the amount of feed and water consumed per animal per replicate. The animals were weighed once a week to determine their weight gain. The experiment lasted for 10 weeks, with the digestibility trial during the last 5 days, during which feces were collected daily from the collection point meant for each animal per treatment. A one-week adjustment period preceded data collection. Dry matter intake (DMI), the initial body weight, weekly body weight, feed intake, and feed conversion ratio were calculated.

PROXIMATE ANALYSIS

The feed and faecal samples were subjected to proximate analyses based on the Association of Official Analytical

Chemists (AOAC, 2012).

STATISTICAL ANALYSIS

The data obtained were subjected to one-way analysis of variance (Genstat, 2013). Mean value variance showing significant ($P < 0.05$) differences were separated using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

The proximate composition of the experimental diets is presented in Table 2, indicating the increase in CP contents as *Tithonia diversifolia* increased in the diet. The CP content of T4 (10.45%) was significantly higher ($P < 0.05$) than that of T1 (7.98%) and T2 (8.80%). The level of *Tithonia diversifolia*, especially at 15% inclusion in this study, demonstrates the plant's quality as a protein source reported to be between 20-30% CP (Animashahun et al., 2024). This indicates that *Tithonia diversifolia* leaf meal in goat diets up to 15% was beneficial for providing the necessary protein content (Omotoso et al., 2024). Importantly, the increase in ether extract enhanced the nutritional value of the diets (Liu et al., 2019). The CF values of diets T2, T3, and T4 were comparable ($P > 0.05$) across the treatments, but the T1 value (14.62) was significantly lower than the other treatments. The comparable crude fiber (CF) content observed in all groups fed diets containing *Tithonia diversifolia* suggests that CF plays a key role in regulating gut fill and providing substrate for rumen microbial activity (Ning et al., 2017). Furthermore, fibre will also sustain rumen motility and buffering capacity, a beneficial factor in goats being intermediate feeders that browse and graze for fibrous forages (Olajide and Adeloje, 2018). The NFE values were gradually reduced as *Tithonia diversifolia* leaf meal increased across the dietary treatments. However, the NFE value (49.72) of T1 was significantly higher ($P < 0.05$), and this may be due the high level of cassava peel in the diet.

Table 2: Proximate composition of the pelleted diets.

Variables	T1	T2	T3	T4	SEM±	p-value
DM%	90.12 ^d	90.35 ^c	90.58 ^b	90.81 ^a	0.11	0.04
MO %	9.88 ^a	9.65 ^b	9.42 ^c	9.19 ^d	0.13	0.04
CP%	7.98 ^c	8.80 ^b	9.63 ^a	10.45 ^a	0.21	0.00
CF%	14.62 ^b	14.98 ^{ab}	15.53 ^a	15.70 ^a	0.18	0.02
EE%	2.96 ^b	3.07 ^{ab}	3.18 ^a	3.29 ^a	0.07	0.03
ASH%	14.84 ^b	15.09 ^{ab}	15.34 ^a	15.59 ^a	0.15	0.02
NFE%	49.72 ^a	48.41 ^b	46.90 ^b	45.78 ^c	0.42	0.00

Means in the same row with common superscripts are not statistically different ($P > 0.05$). DM: Dry matter; MO: Moisture content; CP: Crude protein; CF: Crude fiber; EE: Ether extract; NFE: Nitrogen-free extract.

The level of ether extracts also improved with increasing *Tithonia diversifolia* inclusion, an apparent indication of the presence of plant lipids in the diet, providing useful energy and acceptability for the diets as shown in voluntary increased feed intake in diets containing 10% and 15% *Tithonia diversifolia* leaf meal (Gunun et al., 2024). However, cautionary measures must be taken to avoid excess fat addition from high TDLM inclusion that can impact rumen fermentation. The dry matter (DM) across the diets was consistent, indicating proper drying, which is critical for pellet quality and durability (Retnani et al., 2022), further showing that pelleting under ideal moisture conditions enhances textural integrity and lowers microbial degradation of the feed (Omotoso et al., 2024).

The performance summary of the growing animals fed (Table 3) shows the Total feed intake (TFI) across the groups to be similar ($P > 0.05$), however, the highest value (18.90kg) was recorded for T4, which contained 15% *Tithonia diversifolia*. Goats are known to be selective, showing preferences for particular forages. However, in this study, feed intake was higher at 10% and 15% inclusion levels of *Tithonia diversifolia*, possibly due to improved acceptability and odor, as observed in goats' preference behaviour (Adetunmbi and Chineke, 2022). Conversely, the lower intake at 0% and 5% inclusion levels may be due to reduced fibre content, demonstrating the effect of dietary fibre on gut fill and intake (Ahmed et al., 2024). Physiological and metabolic controls impact feed intake in ruminants; hence, feeds rich in protein and fat (high CP and EE) provide energy rapidly, allowing animals to consume more before feeling full (Liu et al., 2019; Zaher et al., 2022). Importantly, there is also the potential for feed intake to benefit from pelleting, as it could improve diet concentration, reduce dustiness, and decrease selective feeding (Olawoye et al., 2022).

Table 3: Performance of growing WAD goats fed supplemented graded levels of *Tithonia diversifolia* in pelleted cassava peel-based diet.

Parameters	T1	T2	T3	T4	SEM ±	p-value
TFI (kg)	17.92	18.20	18.41	18.90	0.35	0.14
ADFI (g)	256	260	263	270	0.01	0.13
IBW (kg)	5.83	5.33	5.50	6.17	0.78	0.88
FBW (kg)	8.10	7.73	8.94	9.72	0.83	0.82
TWG (kg)	2.27	2.40	3.44	3.55	0.10	0.19
AWWG	0.23	0.24	0.34	0.36	0.02	0.19
ADWG	0.03	0.03	0.05	0.05	0.00	0.20
FCR	7.89	7.58	5.35	5.32	8.34	0.33

TFI: Total feed intake, AWWI: Average weekly feed intake, ADFI: Average daily feed intake, IBW: Initial body weight, FBW: Final body weight, TWG: Total weight gain, AWWG: Average weekly weight gain, ADWG: Average daily weight gain, FCR: Feed conversion ratio.

A significantly ($P < 0.05$) low total weight gain (TWG) of 2.27kg was recorded in T1, while TWG for other groups (T2–T4) values were comparable ($P > 0.05$). The feed conversion ratio (FCR) values obtained in T1, T2, and T3, T4 were similar ($p > 0.05$), respectively. However, the better FCR value (5.32) was obtained in the group fed T4. The ADWG and total weight gain (TWG) in goats fed 15% *Tithonia diversifolia* leaf meal were higher, indicating better nutrient utilization, particularly protein and digestible fibre, resulting from increased available nitrogen and microbial protein synthesis in the rumen (Ajagbe, 2021; Olajide and Adeyoye, 2018). For digestibility (Table 4), the DM values were comparable ($P > 0.05$). The crude protein (CP) 65.25% of T1 was significantly ($P < 0.05$) low, while the highest value (73.08%) was obtained in T4. The respective values of CF and EE recorded at T1 were significantly different ($P < 0.05$) among the treatment groups, while; ASH, ADF, and NDF values across the treatment groups were similar ($P > 0.05$). Although the ADF and NDF values were somewhat lower, they were sufficient for reasonable intake without negatively impacting digestibility (Kolo *et al.*, 2019). This is useful for the growth and tissue synthesis in small ruminants. The observed nutrient digestion trend demonstrates the potential of *Tithonia diversifolia* as a valuable forage supplement. The high digestible crude protein, digestible ether extract, and digestible crude fiber in T4 indicate improved digestibility for the goats as a result of increasing TDLM inclusion levels, which could be due to higher protein, plant lipid, and optimal fiber content (Aye, 2016). This aligns with the potential of browse plants to enhance feed efficiency, supply adequate protein, and provide fermentable carbohydrates that support rumen fibre requirements (Zaher *et al.*, 2022). This is useful for the growth and tissue synthesis in small ruminants.

Table 4: Nutrient digestibility of growing WAD goats fed supplemented graded levels of *Tithonia diversifolia* in pelleted cassava peel-based diet.

Parameters	T1	T2	T3	T4	SEM ±	p-value
DM	91.33	91.67	92.33	92.67	1.94	0.32
MO	8.67	8.33	7.67	7.33	1.92	0.28
ASH	52.20	57.00	60.70	64.00	10.10	0.48
CF	63.10	64.20	67.10	70.60	8.42	0.61
CP	65.25 ^c	67.72 ^{bc}	69.87 ^b	73.08 ^a	0.14	0.02
EE	41.00	42.33	45.00	48.33	1.07	0.62
NDF	44.30	45.70	47.70	52.00	2.77	0.74
ADF	40.30	40.90	43.30	47.00	3.61	0.66

Means in the same row with different superscripts are statistically different ($P < 0.05$). DM: Dry matter; MO: Moisture content; CP: Crude protein; CF: Crude fiber; EE: Ether extract.

One factor that could have enhanced the utilization of *Tithonia diversifolia* is pelleting. By pelleting, the nutrients are banded together in a matrix, which, when taken by goats,

is unaffected until it gets to the rumen, where the pelleted feed is dissolved and available for rumen digestion. This aligns with the fact that pelleting increases bulk density, reduces dustiness, wastage, and ingredient separation, and enhances nutrient digestibility (Massuquetto *et al.*, 2019).

CONCLUSION

The improved performance of the WAD goats demonstrated in this study from the incorporation of *Tithonia diversifolia* as a forage supplement shows that certain browse plants have feeding potential that can provide the required nutrients and fiber contents that will benefit dry-season feeding, which has been a recurring challenge in the tropics.

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AUTHORS CONTRIBUTION

AMB, OSO: Conceptualization, project administration, formal analysis. AMB, OSO, JAO: Data curation, writing, original draft preparation, review, and editing. AMB, OSO, AEA: Investigation, methodology, formal analysis, data gathering. All authors have read and agreed to the manuscript submitted on 22nd of February, 2026.

ETHICAL APPROVAL

This study was in accordance with ethical principles and approved by the Landmark University Ethics Committee via approval number: LUAC/2021/0016A.

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The authors did not receive funding in the course of the study.

GENERATIVE AI AND AI ASSISTED TECHNOLOGY STATEMENT

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

CONFLICT OF INTEREST

The authors have declared no conflict of interest.

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