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Dietary effects of urea-molasses treated maize cob on growth performance and rumen fermentation in West African Dwarf goats

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Abstract: This study evaluated the effects of graded inclusion levels of urea-molasses treated maize cob (UMTMC) in complete diets on growth performance, nutrient digestibility, and rumen fermentation parameters of West African Dwarf (WAD) goats. Fifty goats aged 5 - 7 months were randomly assigned to five dietary treatments (0%, 25%, 50%, 75%, and 100% UMTMC) and fed for 86 days. Results showed that dry matter intake significantly increased at 25% and 50% inclusion levels, peaking at 2.98 kg/day and 2.95 kg/day, respectively, compared to 2.70 kg/day in the control group ($p < 0.05$). Mean weight gain was highest in control (2.20 kg) and declined significantly to 50% and 75% inclusion (0.96 kg), indicating reduced growth efficiency at higher UMTMC levels. Feed conversion ratio was most efficient in the control (13.28) and poorest at 50% and 75% inclusion (22.70). Crude protein digestibility improved significantly at 25% (66%) and 50% (63%) inclusion, while nitrogen retention peaked at 25% (2.80 g/day). Rumen fermentation analysis revealed increased pH, total volatile fatty acids (TVFA), and ammonia nitrogen with rising UMTMC levels. TVFA rose from 95.50mMol/L in control to 125.07mMol/L at 100% inclusion, with significant increases in acetate, propionate, butyrate, and valerate. These findings suggest that UMTMC inclusion up to 50% enhances feed utilization and rumen function without compromising growth, offering a sustainable feeding strategy for small ruminants in tropical regions.

Keywords: West African Dwarf goats; nutrient digestibility; rumen fermentation; nitrogen retention; feed conversion ratio; volatile fatty acids

INTRODUCTION

Small ruminants such as West African Dwarf (WAD) goats play a vital role in the livelihoods of rural households in tropical regions, contributing to food security, income generation, and cultural practices. However, their productivity is often constrained by inadequate nutrition, especially during the dry season when natural pastures decline in quality and quantity, and conventional feed ingredients become scarce or unaffordable (Akinfemi, 2012; Ibrahim et al., 2024). This nutritional bottleneck leads to poor growth rates, reduced reproductive performance, and increased susceptibility to disease, ultimately limiting the economic potential of goat farming in resource-limited settings.

To address these challenges, researchers have explored the use of agro-industrial by-products as alternative feed resources. Maize cob, a fibrous residue from maize harvesting, is abundant in Nigeria and other tropical countries but has limited nutritional value in its raw form due to low protein content and high lignocellulosic structure. However, its nutritive potential can be significantly enhanced through chemical treatment. Urea-molasses treatment improves the nitrogen content and fermentability of maize cob, making it more suitable for ruminant feeding (Adeyemi et al., 2024; Mohammed et al., 2024). Urea provides non-protein nitrogen that supports microbial protein synthesis in the rumen, while molasses serves as a readily fermentable energy source

that stimulates microbial growth and activity (Chijioke et al., 2023; Onen et al., 2023).

The integration of urea-molasses treated maize cob (UMTMC) into complete diets offers a promising strategy for improving feed availability and quality during periods of scarcity. Previous studies have reported improvements in feed intake, digestibility, and rumen fermentation with molasses supplementation and urea-treated roughages (Babatunde et al., 2024; Osman et al., 2020). However, there is limited information on the systemic physiological effects of UMTMC, particularly its impact on growth performance, nutrient digestibility, nitrogen metabolism, and rumen fermentation dynamics in WAD goats.

Understanding these parameters is critical because they reflect the efficiency of nutrient utilization and the metabolic health of the animal. Growth performance indicators such as dry matter intake (DMI), mean weight gain (MWG), and feed conversion ratio (FCR) provide direct measures of productivity. Nutrient digestibility and nitrogen balance offer insights into how well the animal is assimilating and retaining nutrients, while rumen fermentation parameters - including pH, volatile fatty acids (VFAs), and ammonia nitrogen - reveal the functional status of the rumen microbial ecosystem (Hyelda et al., 2017; Brand et al., 1991).

This study was therefore designed to evaluate the effects of graded inclusion levels of UMTMC in complete diets on growth performance, nutrient digestibility, and rumen fermentation in WAD goats. By identifying optimal inclusion rates, the research aims to support the development of cost-effective and nutritionally balanced feeding strategies that enhance small ruminant productivity in tropical smallholder systems.

MATERIALS AND METHODS

Study area

The feeding trial was conducted at the Odora-gunshin Farm Complex of Yaba College of Technology, located along KM 48 Epe-Ijebu-Ode route in Lagos State, Nigeria (Latitude 6°32'N, Longitude 3°56'E). The area experiences a hu-

mid tropical climate with distinct wet and dry seasons, abundant sunshine, and an average annual rainfall of approximately 1 500 mm. ambient temperatures range between 25°C and 34°C.

Preparation of urea-molasses treated maize cob (UMTMC)

Maize cobs were collected from Oba Adetayo Market in Ijebu Ode, sun-dried, and cut into smaller pieces and milled. 100 kg of shredded maize cobs were combined with 100 liters of water, 5 kg of fertilizer-grade urea (purchased from Alibert Plc), and 5 kg of molasses (obtained from Agrose Camps in Ijebu Ode). The mixture was thoroughly homogenized and placed into airtight polyethylene bags, sealed with cellotape, and fermented in the shade for 21 days using the procedure described by Akinfemi et al. (2009). Following fermentation, the modified maize cob was air-dried and added to the experimental diets.

Experimental diets and feed formulation

Five complete diets were formulated by replacing wheat offal with UMTMC at varying levels:

- T1: 0% UMTMC (Control).
- T2: 10% UMTMC.
- T3: 20% UMTMC.
- T4: 30% UMTMC.
- T5: 40% UMTMC.

The diets included maize bran, palm kernel cake (PKC), groundnut cake (GNC), soybean meal (SBM), dicalcium phosphate (DCP), common salt, and a vitamin-mineral premix. To prevent rancidity and maintain palatability, diets were mixed fortnightly and stored in polythene-lined sacks. The gross composition and computed proximal values are shown in Table 1.

Proximate composition of feed ingredients

The proximate compositions of Guinea grass (*Panicum maximum*), wheat offal, and UMTMC were determined using AOAC (2000) methods. The parameters examined were dry matter (DM), crude protein (CP), crude fiber (CF), ether extract (EE), ash, and nitrogen-free extract (NFE). The results are presented in Table 2.

Table 1. Gross Composition of Experimental Diets (% by weight)

Ingredient	DIETS				
	T1	T2	T3	T4	T5
Maize bran	30	30	30	30	30
PKC	10	10	10	10	10
GNC	10	10	10	10	10
Wheat offal	40	30	20	10	0
UMTMC	0	10	20	30	40
Common salt	1	1	1	1	1
DCP	3.75	3.75	3.75	3.75	3.75
SBM	3.75	3.75	3.75	3.75	3.75
Vit. premix	1.5	1.5	1.5	1.5	1.5
Total (kg)	100	100	100	100	100
Calculated analysis					
Crude Protein	16.97	16.32	15.67	15.02	14.37
Crude Fibre	10.13	10.12	10.12	10.12	10.11
Ether Extract	3.87	3.7 5	3.73	3.75	3.56
Ash	4.22	3.92	3.62	3.32	3.02

T1= control, T2= 25% (UMTMC), T3= 50% (UMTMC), T4=75% (UMTMC), T5=100% (UMTMC)

Source: Authors' own elaboration

Table 2. Proximate Composition (% Dry Matter)

Parameters	Guinea. grass	Wheat Offal	UMTMC
Dry matter	43.01	90	95.00
Crude protein	6.88	17.54	9.18
crude fibre	43.49	12.44	18.96
Ether extract	3.10	6.00	2.00
Ash	11.10	6.36	3.64
Nitrogen free extract	35.43	57.66	66.22

Source: Authors' own elaboration

Experimental animals and management

Fifty healthy WAD goats (5 - 7 months old; average initial weight: 5.58 ± 0.42 kg) were obtained at local markets. Upon arrival, the goats were confined for 14 days, dewormed with albendazole (10 mg/kg body weight), treated with long-acting oxytetracycline, and given Amprolium® to prevent coccidiosis. The animals were housed individually in well-ventilated quarters with slat-

ted floors and had unlimited access to clean water and *Panicum maximum* grass.

Experimental design and feeding trial

A completely randomized design (CRD) was implemented. The goats were randomly assigned to five food regimens (T1 - T5), each with ten animals. The feeding trial lasted 86 days, beginning with a 14-day acclimation period. UMTMC diets were supplied as a complement to grazing. Weekly records were kept of feed intake and body weight.

Performance evaluation

Body Weight Gain (BWG):

BWG = Final Weight – Initial Weight

Daily Body Weight Gain (DBWG):

DBWG = BWG ÷ Total Days

Total Feed Intake (TFI):

TFI = Feed Supplied – Feed Leftover

Average Feed Intake (AFI):

AFI = TFI ÷ Number of Goats

Feed Conversion Ratio (FCR):

$$\text{FCR} = \text{TFI} \div \text{BWG}$$

Digestibility and nitrogen balance

At the conclusion of the trial, five goats per treatment were chosen for digestibility testing utilizing total fecal collection. Animals were kept in metabolic cages for 7 days (3 for adaptation and 4 for collecting). Daily feces and urine were collected, weighed, and subsampled for nitrogen analysis. The apparent digestibility coefficients for CP, CF, EE, and ash were calculated. Nitrogen intake, fecal nitrogen, urine nitrogen, nitrogen balance, and retention were all calculated using standard formulae.

Rumen fermentation analysis

Rumen fluid (100 mL) was collected from five goats per treatment using stomach tubing before morning feeding on the final day. A calibrated digital pH meter and thermometer were used to take quick pH and temperature readings. Samples were preserved in 1 mL of 5% orthophosphoric acid and stored at -20°C.

Total VFA: Determined by steam distillation using a Markham micro distillation apparatus (Markham, 1942).

Individual VFAs (acetate, propionate, and butyrate): Quantified via gas chromatography (Merbauis, 1992).

Ammonia Nitrogen (NH₃-N): Measured using standard spectrophotometric methods.

Statistical analysis

All data were subjected to one-way ANOVA with SPSS version 25.0. Duncan's multiple range test was used to differentiate treatment means at a p-value of less than 0.05. The results are shown as means $\pm$ standard error of mean (SEM).

RESULTS**Growth performance**

Table 3 provides a summary of how dietary UMTMC addition affects growth measures. A number of parameters were evaluated, including feed conversion ratio (FCR), mean weight gain (MWT), initial and final body weights (IBW and FBW), and dry matter intake (DMI). Performance differences across treatments shed light on the ideal level of UMTMC incorporation for development efficiency.

The inclusion of UMTMC in goat diets had a significant impact on feed intake and growth metrics. Dry matter intake (DMI) increased notably to 25% and 50% inclusion levels, with values of 2.98 kg/day and 2.95 kg/day, respectively, compared to 2.70 kg/day in the control group. This suggests that moderate levels of UMTMC

Table 3. Growth performance of WAD goats fed urea-molasses treated maize cob experimental diets

Parameters	DIETS					SEM	p-value
	T1	T2	T3	T4	T5		
DMI	2.70b	2.98b	2.95a	2.84ab	2.79b	0.26	0.001
IBW	5.70a	5.70a	5.23a	5.53a	4.76a	0.38	0.001
FBW	7.90a	8.00a	8.23a	7.50a	7.50a	0.38	0.001
MWT	2.20a	1.80ab	0.96b	0.96b	1.73ab	0.18	0.007
FCR	13.28b	15.35ab	22.70a	22.70a	13.56ab	1.59	0.002

^{ab} means along the same column with different superscript are significantly different ($p < 0.05$)

DMI- Dry matter intake, IBW-initial body weight, FBW-final body weight, MWT-mean weight, FCR-feed conversion ratio, SEM- standard error of mean, T1= control, T2= 25% (UMTMC), T3= 50% (UMTMC), T4=75% (UMTMC), T5=100% (UMTMC)

Source: Authors' own elaboration

enhance palatability and rumen fill, likely due to the sweet taste and fermentable nature of molasses (Osman et al., 2020). However, at 75% and 100% inclusion, DMI declined slightly, indicating potential limitations in palatability or digestibility at higher fiber concentrations.

The initial body weights of all groups were statistically identical, suggesting consistency at the outset of the trial. Final body weights and mean weight gain (MWG) decreased as UMTMC levels increased. The control group had the highest MWG (2.20 kg), but the 50% and 75% inclusion groups had considerably reduced gains (0.96 kg), indicating that excessive fiber may limit nutritional density and energy availability (Mohammed et al., 2024). Feed conversion ratio (FCR) was highest in the control group (13.28), indicating improved feed usage. FCR values decreased to 50% and 75% inclusion (22.70), indicating decreased efficiency, probably due to lower protein and energy contents.

Nutrient digestibility and nitrogen balance

In addition to nitrogen intake, excretion, and retention, Table 4 provides the digestibility coefficients for crude protein (CP), crude fiber (CF), ether extract (EE), and ash. These values show

how well nutrients are used physiologically and how well nitrogen is metabolized in goat-fed diets with different amounts of UMTMC.

Crude protein digestibility was highest at 25% UMTMC (66%), followed by 50% (63%), both significantly superior to the control (33%). This improvement is related to increased rumen microbial activity aided by urea and molasses, which promote protein breakdown and assimilation (Hyelda et al., 2017). Crude fiber digestibility remained generally consistent across treatments, showing that fiber degradation was not considerably reduced even at increased inclusion levels.

Ether extract digestibility peaked at 25% inclusion (0.10), indicating increased lipid absorption due to molasses-enhanced energy availability. Ash digestibility was best at 50% inclusion (0.27), indicating improved mineral consumption. Nitrogen intake and retention increased significantly at 25% and 50% inclusion, with nitrogen balance values of 2.79 g/day and 1.96 g/day, respectively, compared to 0.28 g/day in the control group. These findings demonstrate that moderate UMTMC levels improve nitrogen consumption, which is critical for microbial growth and protein synthesis.

Table 4. Apparent nutrient digestibility and nitrogen balance of WAD goats' urea-molasses treated maize cob (UMTMC) experimental diets

Parameters	DIETS					SEM	p-value
	T1	T2	T3	T4	T5		
CP digestibility	0.33b	0.66a	0.63a	0.39ab	0.14b	0.04	0.001
CF digestibility	0.51a	0.34a	0.47a	0.57a	0.49a	0.04	0.001
EE digestibility	0.07b	0.10a	0.04c	0.06b	0.06b	0.01	0.001
ASH digestibility	0.21b	0.18bc	0.27a	0.18c	0.13d	0.01	0.001
N-intake (g/d)	1.79c	3.93a	3.42b	3.33b	1.79c	0.02	0.001
Faecal-N(g/d)	0.74c	0.66d	0.79b	0.98a	0.56c	0.01	0.001
Urinary-N(g/d)	0.77b	0.47d	0.66c	0.94a	0.47d	0.01	0.001
N-Balance(g/d)	0.28e	2.79a	1.96b	1.40c	0.74d	0.02	0.001
N-retention(g/d)	0.28e	2.80a	1.97b	1.41c	0.76d	0.05	0.001

^{a-e} means along the same column with different superscript are significantly different ($p<0.05$)
SEM- standard error of mean, T1= control, T2= 25% (UMTMC), T3= 50% (UMTMC), T4=75% (UMTMC), T5=100% (UMTMC).

Source: Authors' own elaboration

Rumen fermentation parameters

Table 5 provides information on pH, total volatile fatty acids (TVFA), individual VFA profiles (acetic, propionic, butyric, and valeric acids), ammonia nitrogen (NH₃-N), and rumen temperature in order to better understand how UMTMC affects rumen function. Microbial activity and fermentation efficiency, which are essential for nutrient absorption, are indicated by these metrics.

Rumen pH gradually increased with UMTMC inclusion, reaching 5.61 at 100%, indicating higher buffering capacity and a suitable environment for microbial activity. Total volatile fatty acid (TVFA) content increased from 95.50mMol/L in the control to 125.07mMol/L with 100% inclusion, indicating increased fermentation and energy generation. Individual VFAs - acetate, propionate, butyrate, and valerate - all increased significantly, with acetate and propionate exhibiting the greatest increase. These VFAs are necessary for energy metabolism and indicate proper carbohydrate and fiber digestion (Chijioke et al., 2023).

Ammonia nitrogen levels were considerably greater in treated groups, reaching 0.38mMol/L at 100% inclusion. This means that more nitrogen is available for microbial protein synthesis, which is important for rumen function and animal growth. The rumen temperature stayed within the optimum range (30 - 32°C), resulting in steady microbial kinetics and fermentation efficiency.

DISCUSSION

This study found that moderate inclusion of UMTMC (25 - 50%) in complete meals significantly increases feed intake, nutritional digestibility, nitrogen retention, and rumen fermentation in WAD goats. These findings are similar with prior study, which found that molasses supplementation improves palatability and energy supply while urea treatment increases nitrogen availability for microbial synthesis (Osman et al., 2020; Babatunde et al., 2024).

The increase in dry matter intake at moderate inclusion levels is due to better feed acceptance and rumen fill, both of which are necessary for voluntary intake and production. However, the loss in weight increase and feed efficiency at higher inclusion levels (75 - 100%), shows that excessive fiber and low protein content may compromise food absorption and energy balance (Mohammed et al., 2024; Brand et al., 1991). This emphasizes the need of balancing fiber and protein in diet composition to prevent unfavorable effects on growth performance.

At 25% and 50% inclusion levels, UMTMC improves crude protein digestibility and nitrogen retention, demonstrating its efficacy in boosting microbial activity and protein metabolism. These findings are consistent with those published by Hyelda et al. (2017), who found better nitrogen consumption in goats given urea-treated crop

Table 5. Effect of urea-molasses treated maize cob on rumen fermentation parameters of WAD goats

Treatment	pH	TVFA	ACETIC	PROPIONIC	BUTYRIC	VALERIC	NH ₃ -N	TEMP
T1	5.32c	95.50d	7.55c	7.42d	6.79e	6.97c	0.22b	30.17b
T2	5.37b	96.62d	7.64d	7.46d	6.97d	7.02c	0.35a	30.57ab
T3	5.32c	111.98c	8.78d	8.47c	7.99c	7.97b	0.35a	32.03a
T4	5.37b	114.50b	8.99b	8.76b	8.29b	8.14b	0.35a	32.03a
T5	5.61a	125.07a	9.89a	9.44a	8.97a	8.93a	0.38a	31.57ab
SEM	0.05	0.34	0.006	0.015	0.076	0.03	0.015	0.26
p-value	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001

^{a-d} means along the same column with different superscript are significantly different ($p < 0.05$)

SEM- standard error of mean, T1= control, T2= 25% (UMTMC), T3= 50% (UMTMC), T4=75% (UMTMC), T5=100% (UMTMC).

Source: Authors' own elaboration

wastes. The increased ammonia nitrogen and volatile fatty acid concentrations support the hypothesis that UMTMC improves rumen fermentation, resulting in increased energy availability and microbial protein synthesis.

The increase in VFAs, notably acetate and propionate, suggests that carbs and fiber are efficiently fermented, which is necessary for energy metabolism and tissue formation. These findings are corroborated by Chijioke et al. (2023) and Onen et al. (2023), who found comparable patterns in goats fed molasses-supplemented diets.

In conclusion, UMTMC represents a promising technique for enhancing feed quality and animal performance in tropical goat production systems. However, inclusion levels should be carefully controlled to minimize the deleterious consequences of excessive fiber and low nutritional density.

CONCLUSION

The introduction of urea-molasses treated maize cob (UMTMC) in the diets of West African Dwarf goats had a substantial impact on feed intake, nutritional digestibility, nitrogen use, and rumen fermentation dynamics. Moderate inclusion levels (25 - 50%) demonstrated to be appropriate, increasing dry matter intake, crude protein digestibility, and nitrogen retention, while also sustaining favorable rumen conditions for microbial activity and volatile fatty acid synthesis. These changes resulted in increased feed utilization and metabolic efficiency, showing urea and molasses' synergistic effects in improving low-quality fibrous feed resources.

Higher inclusion levels (75 - 100%), on the other hand, were linked to lower growth performance and feed conversion efficiency, most likely due to increased fiber and reduced nutritional density. This emphasizes the significance of balancing energy and protein sources when designing meals using treated crop waste.

Overall, UMTMC is a viable and sustainable alternative to traditional feed ingredients, espe-

cially during feed scarcity situations in tropical settings. Its judicious usage at moderate levels can boost production and lower feeding costs in small ruminant systems. Future research should investigate long-term health effects, reproductive performance, and economic feasibility to help validate its use in larger animal production scenarios.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made to improve the usage of urea-molasses treated maize cob (UMTMC) in small ruminant nutrition:

1. **Optimal Inclusion Level:** Incorporate UMTMC at a moderate level (25-50%) in complete diets for West African Dwarf goats to improve feed intake, nutritional digestibility, and rumen fermentation without affecting growth performance.

2. **Avoid Excessive Fiber Load:** Including more than 50% fiber is not recommended as it can limit weight gain and feed conversion efficiency due to low nutritional density. Diets should be carefully balanced to ensure enough energy and protein intake.

3. **Adoption in Feed-Scarce Seasons:** UMTMC is a cost-effective and sustainable alternative to conventional feed ingredients, particularly during dry seasons when feed is scarce. Its application can reduce reliance on commercial concentrates while increasing resilience in smallholder systems.

4. **Farmer Training and Extension Services:** To ensure consistent feed quality and reduce nutrient loss during fermentation, livestock farmers should get training in preparing, storing, and using UMTMC safely.

5. **Future Research:** Studies should investigate the long-term effects of UMTMC on reproductive performance, immunological response, carcass quality, and economic viability to promote its widespread use in various production systems.

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