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Nutrient digestibility, nitrogen balance and rumen fermentation parameters of West African dwarf goats offered treated maize stover supplemented with *Gmelina arborea*

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Abstract

A large portion of agricultural crop residues are potential feed resources for ruminants in the tropics. This study therefore, investigated the intake, nutrient digestibility, nitrogen utilisation and rumen fermentation parameters of West African dwarf goats (WAD) fed treated and untreated maize stover supplemented with *Gmelina arborea*. Twenty male WAD goats (11.50 ± 0.45 kg body weight) were randomly allotted into four treatments with five animals each. Untreated maize stover (MS), urea treated maize stover (UT), molasses treated maize stover (MT) and urea-molasses treated maize stover (UMT) were supplemented with 300 g *Gmelina arborea* (G) and were offered to each group for three weeks. MS had highest dry matter (DM; 87.1 %), neutral detergent fibre (76 %), acid detergent fibre (45 %) and acid detergent lignin (6 %) contents $p < 0.05$. Crude protein content was high in UT (12.5 %) and UMT (13 %). Animals fed UMT+G recorded higher DM intake and digestibility, whereas crude protein digestibility was higher in animals on UT+G (72.8 %) and UMT+G (76.2 %). Nitrogen intake was more in goats fed UMT+G (P<0.05) and least in MS+G fed group. Higher nitrogen was absorbed and retained by goats on UMT+G. The pH of the ruminal fluid was not affected by the dietary treatments. Concentrations of ammonia nitrogen and total volatile fatty acids were higher in UMT+G fed animals. Thus, UMT+G is a good option for proper nutritional utilisation of maize stover which can easily be adopted by farmers given the availability of materials (*Gmelina arborea*, maize stover, urea and molasses) and simplicity of the technology involved in the treatment of the stover.

Keywords: crop residue, feed intervention, molasses, Nigeria, nutrient utilisation, urea

1 Introduction

One of the major problems affecting livestock production in the tropics is quantitative and qualitative feeding during the dry season. Ruminant owners raise their animals on natural grasses, which are intrinsically poor in nutritive value, low in digestibility and scarce during the dry season (Babayemi *et al.*, 2009). The animals are therefore poorly nourished, which eventually affect their productivity. Goat is one of the most important small ruminant livestock species that produces a good source of meat and milk for human consumption. It represents about 30 % of ruminant livestock in Africa and the largest group of small ruminant livestock in Nigeria (FAOSTAT, 2011). About 85 % of rural households and small time business people keep goats (FDLPCS, 2007). The West African dwarf goat is the most common and an indigenous breed in the West and Central African countries (Chiejina & Behnke, 2011). Most goats are reared on free range and trek for long distance in search of feed especially during the dry season which may have adverse effect on their performance. In Africa, Nigeria in particular, several crop residues are available in large quantities during harvesting of crops, some of which have been found to be potential feed resources for ruminants as they are readily degraded in the rumen (Belewu, 2001). Others, especially residues from cereal crops, are of poor nutritive value and require treatment or supplementation to boost their feeding value potential. All these can serve as alternative feed re-

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sources for ruminants during the period of forage scarcity. Maize (*Zea mays* L.) is the common food crop grown by a majority of smallholder farmers with abundant residues, i.e maize stover, being generated. In Nigeria, and other parts of the world, maize stover is usually burnt or incorporated into the soil after harvesting of the maize cob in preparation of the land for the next cropping season (Ansah *et al*., 2006; Issaka *et al*., 2012; Punyalue *et al*., 2015). Only few farmers utilise these as animal feed as maize stover is low in protein, digestibility and has high lignin content (Girma *et al*., 2009). The high lignin content affects its voluntary intake and digestibility, which may in turn affect the microbial activity in the rumen. The crude protein content of maize stover varies between 2.3 % (Kabatange & Shayo, 1991) and 7.1 % (Woyengo *et al*., 2004) and thus, can be treated and/or supplemented to increase its nutritional value such as treatments by various forms (physical, chemical, and biological) and supplementation with feeds rich in protein and energy (Hirut *et al*., 2011). Urea has been used to improve the nutritive value of poor quality crop residues (Akinbode *et al*., 2016; Abera *et al*., 2018) because it is cheap and easy to handle (Sahnoune *et al*., 1991). Molasses is a source of fermentable sugars and minerals, and has been used to increase the feeding value of low quality crop residues (Lima *et al*., 2010; Chen *et al*; 2014). However, treating poor quality roughages with urea or molasses may not be adequate for production functions like growth, pregnancy and lactation (Brand *et al*., 1991) or may hardly support animal performance above maintenance requirement unless it is supplemented (Orden *et al*., 2000). Woyengo *et al*. (2004) and Abera *et al*. (2018) reported better utilisation of stover treated with both urea and molasses, when supplemented with concentrate feed. However, concentrate feed is expensive and may not be affordable by many farmers. Therefore, supplementation with multipurpose trees or browse plants, which are readily available all year round, could improve the utilisation of treated maize stover. Multipurpose tree legumes have been shown to supply protein, digestible energy and mineral, when fed alone or as supplement (Abdulrazak *et al*., 1997). Tolera & Sundstøl (2000) explained that supplementation of cereal crop residues with legume forages led to increased ammonia-nitrogen concentration, microbial nitrogen and volatile fatty acids in rumen fluid. In Nigeria, one of the commonly available, fast growing multipurpose trees with appreciable production of forage at the peak of dry season is *Gmelina arborea*. It is a leading tropical plantation tree species that grows up to 21 m high and 1.8 m in girth (Osakwe & Udeogu, 2007). *Gmelina arborea* supplies forage and fodder all year-round and has been recognised as one of the most preferred browse species by ruminants especially sheep and goats during the dry season (Adu *et al*., 1996; Omokanye *et al*., 2001). This study therefore, investigated the digestibility, nitrogen utilisation and rumen fermentation parameters of West African dwarf (WAD) goats fed treated and untreated maize stover supplemented with *Gmelina arborea*.

2 Materials and methods

2.1 Study area

The study was carried out at the Small Ruminant Unit, College of Animal Science and Livestock Production (COLANIM) farm of the Federal University of Agriculture, Abeokuta, Nigeria, which is situated in the rainforest zone of southwestern Nigeria at latitude 7°13’28” N and longitude 3°25’2” E. The annual mean temperature is 34.7 °C and the relative humidity of the study site is high during the raining season with values ranging between 63 and 96 % as compared to dry season values of 55 to 84 % (Anele *et al*., 2011)

2.2 Sourcing and preparation of experimental feed

Maize stover was collected after harvesting of maize cobs at the premises of the Federal University of Agriculture, Abeokuta. It was chopped to about 4 cm length and treated with urea (4 %) and/or molasses (5 %). 400 g of urea was dissolved in 10 litres of water for 20 minutes and then mixed with 10 kg stover (urea treated maize stover (UT)). 500 g of molasses was also mixed in 10 litres water and thoroughly mixed with 10 kg maize stover (molasses treated maize stover (MT)). Urea-molasses treated maize stover (UMT) was prepared by adding 400g of urea to 10 litres water and mixed very well until the urea dissolved in the solution. Then, 500 g of molasses was added into urea solution and mixed up. The solution was then uniformly distributed and thoroughly mixed with 10 kg maize stover. UT, MT and UMT were then packed firmly by compacting each layer into separate containers already double lined with black polythene sheets. After filling, the polythene sheets were tightly tied and a sand bag of about 25 kg was placed on it before being sealed for 14 days to avoid air penetration. *Gmelina arborea* was harvested at the arboretum of the University farm and air dried for 5 days prior feeding to animals.

2.3 Experimental animals, management and diets

An intake and digestibility trial was carried out for three weeks using twenty growing West African dwarf bucks with an average weight of 11.50 ± 0.45 kg. West African dwarf goat was used in this study being the most common and the most indigenous breed in south western Nigeria. The animals were randomly divided into four groups of five animals each and were housed individually in disinfected metabolic cages. Animals had access to fresh clean water throughout the experiment. The first two weeks were a preliminary period, while the third week was used for total faeces and urine collection. All the four treatments (untreated maize stover (MS), UT, MT and UMT) were fed to animals on ad libitum basis at 8.00 am and supplemented with 300 g *Gmelina arborea* (G) per goat per day at 4.00 pm. The UT and UMT were aerated for 24 hours prior to feeding to allow escape of ammonia.

2.4 *Apparent digestibility and nitrogen balance measurements*

Apparent nutrient digestibility was determined by means of the total faecal and urine collection method. The daily intake of maize stover and *Gmelina arborea* was calculated by removal of feed refused from the feed offered. Faeces and urine of each animal were collected daily, weighed and 10 % aliquot were stored at -20 °C. The urine was collected in bottles containing 2 mL of 10 % sulphuric acid for preservation purpose. At the end of collection period, faecal and urine samples of each animal were pooled, thoroughly mixed and 10 % of the total amount was taken for the chemical analysis. Samples of feed and faecal for each treatment were oven dried at 65 °C until constant weight was attained for dry matter (DM) determination. Crude protein (CP), ash and ether extract were determined using the methods of AOAC (2005), while neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were analysed according to Van Soest *et al*. (1991). Apparent digestibility of nutrients was calculated as the difference between the nutrient content of the feed consumed and of faeces, as percentage of its intake:

$$\text{Digestibility (\%)} = \frac{\text{nutrient intake (g/day)} - \text{faecal nutrient (g/day)}}{\text{nutrient intake (g/day)}} \times 100$$

Urine samples were also analysed to determine nitrogen content and consequently, the nitrogen retention was calculated.

2.5 *Rumen fluid analysis*

During the last day of intake and digestibility study, approximately 30 mL of ruminal fluid was collected from each animal four hours after morning feeding. The fluids were strained through four layers of cheese cloth, after which the pH was determined using a pH metre. From each rumen fluid sample, 15 mL was frozen and stored at -20°C for later determination of total volatile fatty acid (TVFA) concentration. TVFA was determined using Markham apparatus as described by Barnett & Reid (1956). This was done by adding 2 mL of rumen fluid together with 1 mL 10 % potassium oxalate buffer and 1 mL oxalic acid injected into the Markham apparatus, where a distillate of 100 mL was collected. This was then subsequently titrated against a standard 0.01 N NaOH with 2 drops of phenolphthalein as indicator. Concentration of TVFA was then calculated using the following equation:

$$\text{TVFA (mM)} = \frac{\text{(NaOH volume} \times \text{NaOH normality} \times 1000)}{\text{rumen inoculum volume}}$$

From each rumen fluid sample, another 15 mL was acidified with a few drops of concentrated sulphuric acid, frozen and stored for determination of ammonia nitrogen concentration using steam distillation procedures (Ogubai & Sereke, 1997).

2.6 *Statistical analysis*

All data collected were subjected to one-way Analysis of Variance. Duncan's Multiple range Test (SAS, 1999) was used to compare significant differences among means. The mathematical model for the study is thus:

$$Y_{ij} = \mu + T_i + \Sigma_{ij}$$

where Y_{ij} = observed values of dependent variables, μ = population mean, T_i = effect of different treatments, Σ_{ij} = random residual error

3 Results

Table 1 presents the chemical composition of treated and untreated maize stover, and *Gmelina arborea* fed to the animals in this study. MS recorded the highest dry matter content, which was significantly different from that of other treatments ($p < 0.05$). Crude protein content was high in UT (12.5 %) and UMT (13.0 %), medium in MT (9.6 %) and lowest in MS (7.2 %; $p < 0.05$). NDF (76 %) and ADF (45 %) contents were more in MS when compared to other treatments ($p < 0.05$). However, ash and ether extract contents of all treatments were similar.

Table 2 shows the dry matter intake (DMI) of WAD goats fed treated and untreated maize stover supplemented with *Gmelina arborea* and the apparent nutrient digestibility of each treatment. There were significant differences in all the parameters considered except *Gmelina arborea* intake which was similar across the treatments. Animals fed UMT+G recorded highest dry matter intake (501.5 g day^{-1}) and digestibility (77.5 %), while those on MS+G had the lowest values ($p < 0.05$). Crude protein digestibility was high in animal fed UMT+G (76.2 %) and UT+G (72.8 %). All animals fed

Table 1: *Chemical composition (%) of untreated maize stover (MS), urea treated maize stover (UT), molasses treated maize stover (MS), urea-molasses treated maize stover (UMT) and Gmelina arborea (G) used for the study*

	treatments					
parameters	*MS*	*UT*	*MT*	*UMT*	*SEM*	*G*
Dry matter	87.1^a	67.9^b	70.0^b	67.4^b	4.30	46.1
Crude protein	7.2^c	12.5^a	9.6^b	13.0^a	0.66	14.0
Ether extract	2.7	2.8	2.5	2.7	0.23	5.3
Ash	10.3	11.0	11.0	12.2	0.32	7.8
NDF	76.0^a	66.0^b	64.0^{bc}	62.0^c	5.88	54.3
ADF	45.0^a	40.0^b	43.0^b	42.3^b	0.56	40.7
ADL	6.0	5.3	5.6	4.1	0.42	3.8

^{abc} Means on the same row with different superscripts are statistically different ($p < 0.05$); Values of *Gmelina arborea* are excluded.
NDF: neutral detergent fibre; ADF: acid detergent fibre; ADL: acid detergent lignin; SEM: standard error of mean.

Table 2: *Dry matter Intake and apparent nutrient digestibility of West African dwarf goats fed untreated maize stover (MS), urea treated maize stover (UT), molasses treated maize stover (MT), urea-molasses treated maize stover (UMT) supplemented with Gmelina arborea (G)*

	treatments				
parameters	*MS+G*	*UT+G*	*MT+G*	*UMT+G*	*SEM*
DMI (g day^{-1})					
Maize stover	251.6^d	312.6^c	345.6^b	364.7^a	13.14
G. arborea	137.4	132.5	133.5	136.7	1.32
Total	388.9^d	445.1^c	479.1^b	501.5^a	13.05
digestibility (%)					
DM	54.4^c	73.5^b	72.8^b	77.5^a	1.48
Crude protein	56.8^c	72.8^{ab}	65.2^b	76.2^a	2.47
Ether extract	55.2^c	65.6^a	64.2^a	66.8^a	1.45
Ash	51.1^b	57.1^{ab}	50.9^b	63.4^a	1.87
NDF	57.9^c	69.8^b	67.9^b	73.3^a	1.76
ADF	45.3^c	51.4^b	52.2^b	58.2^a	1.73

^{abc} Means on the same row with different superscripts are statistically different ($p < 0.05$);
NDF: neutral detergent fibre; ADF: acid detergent fibre; ADL: acid detergent lignin; SEM: standard error of mean.

treated maize stover recorded high values for ether extract digestibility when compared to those on untreated maize stover. The NDF and ADF digestibility followed the same trend with animals on UMT+G having the highest value and MS+G fed animals with the least value. Ash digestibility was higher for animals on UMT+G (63.4 %) when compared to those on MT+G (50.9 %) and MSG (51.1 %; $p < 0.05$). Ash digestibility of animals fed UT+G (57.1 %) did not significantly vary from other treatments.

Nitrogen balance, pH, ammonia nitrogen and total volatile fatty acids of WAD goats fed treated and untreated maize stover supplemented with *Gmelina arborea* is presented in Table 3. Nitrogen intake was highest in goats fed UMT+G (10.6 g day^{-1}) followed by those on UT+G (9.2 g day^{-1}) and MT+G (8.3 g day^{-1}), while MS+G fed animals recorded the least value (5.9 g day^{-1}; $p < 0.05$). Urinary nitrogen was more in animals fed UT+G (2.3 g day^{-1}) and UMT+G (2.0 g day^{-1}) than those on other treatments ($p < 0.05$). Animals on UT+G recorded highest total nitrogen excretion compared with those on other treatments ($p < 0.05$). Higher nitrogen was absorbed (8.4 g day^{-1}) and retained (6.4 g day^{-1}) by goats on UMT+G. Nitrogen retained as percentage of nitrogen intake also followed the same trend.

There was no significant difference in the ruminal fluid pH of animals across the treatments. The pH ranged from 6.4 to 6.7. Ammonia nitrogen and total volatile fatty acid concentrations were significantly higher in animals fed UMT+G (31.9 % and 130.5mM) and lowest in those on MS+G, ($p < 0.05$).

4 Discussion

The chemical composition of maize stover obtained in this study was in line with what was reported in previous studies (Methu *et al.*, 2001; Assefa *et al.*, 2013). However, the crude protein content of untreated maize stover obtained was higher than those reported by Koralagama *et al.* (2008) and Abera *et al.* (2018) but was within the range of 7.1 – 7.4 % reported in some studies (Methu *et al.*, 2001; Woyengo *et al.*, 2004; Assefa *et al.*, 2013). The values of 72.5 %, 44.9 %, 6.2 % and 9.2 % reported for NDF, ADF, ADL and ash contents respectively by Assefa *et al.* (2013) were comparable to the values obtained in this study for untreated maize stover. Differences observed with respect to some other studies may be attributed to differences in growing conditions and variety of the crop. Also, leaf:stem ratio and time of harvesting are other factors (which were not considered in this study) that affect the composition of maize stover as stover with low leaf : stem ratio is likely to contain low CP level (Methu *et al.*, 2001) and high level of cell wall constituents. The crude protein, ether extract and ash contents of *Gmelina arborea* used in this study was lower than the values (21.1 %, 23.8 % and 8.40 % respectively) reported by Omokanye *et al.* (2014) but with similar NDF and ADF contents. However, Augustine *et al.* (2018) reported similar crude protein (13.2 %), ether extract (4.5 %) and ash (6 %) contents with those obtained in this study. The chemical composition of *Gmelina arborea* revealed its potential as supplement to enhance intake and utilisation of fibrous crop residues by ruminants due to its high crude protein and low fibre contents. High ash content (7.8 %) of *Gmelina arborea* showed its po-

Table 3: *Nitrogen balance, pH, ammonia nitrogen and total volatile fatty acids of West African dwarf goats fed untreated maize stover (MS), urea treated maize stover (UT), molasses treated maize stover (MT), urea-molasses treated maize stover (UMT) supplemented with Gmelina arborea (G)*

	treatments				
parameters	*MS+G*	*UT+G*	*MT+G*	*UMT+G*	*SEM*
N-intake (g day^{-1})	5.9^{c}	9.2^{b}	8.3^{b}	10.6^{a}	0.61
Faecal-N (g day^{-1})	2.5^{a}	2.3^{b}	2.3^{b}	2.2^{b}	0.12
Urinary-N (g day^{-1})	1.2^{a}	2.3^{a}	1.8^{a}	2.0^{ab}	0.13
Total N-excretion (g day^{-1})	3.7^{a}	4.6^{a}	4.1^{a}	4.2^{a}	0.20
N-absorbed (g day^{-1})	3.5^{a}	6.9^{a}	6.0^{a}	8.4^{a}	0.58
N-retained (g day^{-1})	2.3^{a}	4.6^{a}	4.3^{a}	6.4^{a}	0.48
N-retained (% of N-intake)	37.8^{a}	49.8^{a}	51.2^{a}	60.4^{a}	1.97
pH	6.7	6.6	6.4	6.6	0.16
Ammonia-nitrogen (mg/dL)	16.9^{c}	22.1^{a}	20.4^{a}	31.9^{a}	1.58
Total volatile fatty acids (mM)	59.1^{c}	84.1^{a}	78.1^{a}	130.5^{a}	2.74

^{abc} Means on the same row with different superscripts are statistically different ($p < 0.05$); N: Nitrogen; SEM: standard error of mean.

tential as a good source of minerals for goats when fed as supplement to low quality roughages.

Higher crude protein and lower cell wall constituents observed in all treated maize stover was a result of urea and molasses added to the stover. The increase in crude protein content was a direct effect of urea addition which is a source of non-protein nitrogen (NPN) in ruminant diets, while the ability of urea to break down the lignin bond thereby dissolving the hemicelluloses may be responsible for the decreased NDF, ADF and ADL observed in the treated stovers. Similar observations have been reported in earlier studies (Yadete, 2014; Elias & Fulpagare, 2015; Abera *et al.*, 2018).

The total DMI was highest for animals fed UMT+G (501.5 g day^{-1}). This might be a result of high CP content of this diet as Lu & Potchoiba (1990) noted that DMI increased linearly as dietary CP level increased for growing goats. The advantage of treating the stover with the combination of urea and molasses may also have a positive impact on the taste of the stover and hence the increased intake. It has been reported that diets of crop residues treated with urea-molasses mixture improved the intake of feed in cattle and sheep (Singh & Klopfenstein, 2001). Lower NDF content of UMT might be another factor responsible for the higher intake as NDF is indirectly related to intake (Bell, 1997) i.e the lower the NDF, the higher the intake. This is one of the advantages of feeding UMT over other treatments as the nutrient intake of animals will also increase. The reduced intake observed in goats fed UT+G (388.9 g day^{-1}) compared to other treated stovers could be a result of pungent smell and bitter taste of urea. The lowest dry matter intake recorded in animals fed MS+G might be a result of the low DM digestibility of this treatment as feed intake is related to digestibility, which later affects the rate of feed passage and intake. However, the dry matter intake observed in goats across the treatments in this study was within the range (360–582 g day^{-1}) reported by Wambui *et al.* (2006), for growing goats in Kenya fed with urea treated maize stover supplemented with Tithonia, Calliandra and Sesbania, which are also browse pants.

The apparent dry matter digestibility recorded in animals placed on MS+G (54.4 %) was lower than the values of 61.4 % reported by Woyengo *et al.* (2004) and of 61 % reported by Abera *et al.* (2018), when untreated maize stover was supplemented with concentrate mixture or cotton seed cake. Apparent dry matter digestibility of MS+G was however higher than the 44.5 % reported by Woyengo *et al.* (2004) for untreated maize stover. This revealed the positive effect of *Gmelina arborea* supplementation to the untreated maize stover. All the treated stover recorded higher DM digestibility when compared with the control, in agreement with Dass *et al.* (1996), who stated that supplementation of ruminant animals fed on low quality roughages with carbohydrate and protein sources such as molasses and urea could improve the digestibility and bioavailability of nutrients. Animals on UMT+G had 42 % increase in dry matter digestibility when compared with those on MS+G. This makes UMT+G a very good feed intervention to implement by farmers because improved digestibility of feedstuffs results to increased animal performance in terms of increased weight gain and milk production. High crude protein digestibility obtained in all treated maize stover was in line with the findings of previous studies (Yadete, 2014; Elias & Fulpagare, 2015). Kusmartono (2002) also reported improved digestibility in both sheep and steers when rice straw was supplemented with nitrogen sources (molasses-urea block) or Gliricidia leaves. However, the low crude protein digestibility obtained in animals kept on MS+G (56.8 %) in this study was higher than the 30.8 % found by Woyengo *et al.* (2004) when untreated maize stover was fed to red Maasai sheep. The increase could have resulted from *Gmelina arborea* supplementation potentially supplying more nitrogen, which improved the digestion of crude protein. The NDF and ADF digestibility were higher in animals placed on UMT+G. This shows that substantial part of the fibre ingested by these animals was fermented in the rumen for energy and microbial protein production. In general, higher NDF digestibility will result in higher digestible energy and intake which will in turn improve the general performance of the animals. The higher nitrogen intakes recorded in the treated groups may be related to the higher dry matter intake and crude protein content of these diets, this is supported by the observation of McDonald *et al.* (1996) that dietary nitrogen intake is directly related to the proportion of nitrogen in the diet of animals. The faecal nitrogen was more in MS+G fed group which also had the least crude protein digestibility, in agreement with the findings of Mousa (2011), who reported that crude protein digestibility coefficient reflects the amount of N excreted in the faeces. The higher urinary and total nitrogen excretion in UT+G fed group, may be due to non-inclusion of molasses in this treatment as Hao & Ledin (2001) stated that an increase in degradable nitrogen losses through urine and faeces was a result of lack or insufficient energy in the diets. It was observed in this study that treatments (UT+G and UMT+G) with higher nitrogen intake also recorded higher urinary nitrogen in agreement with Van Soest (1994), who noted that an increased nitrogen intake is associated with increase in the urea production in the liver and consequently its excretion in the urine. Nitrogen retention also depends on the intake of nitrogen and the amount of fermentable carbohydrate in the diet (Sarwar *et al.*, 2003); hence the higher nitrogen retained observed in UMT+G treatment. This implies that feeding animals with UMT+G can improve weight gain, increase nutrient composition of milk, and improve immune response of animals; which are all advantages of feeding enough dietary protein to animals. However, all animals had a positive nitrogen balance, which implied that the animals utilised the diets offered effectively.

The ruminal pH range obtained in this study was within the range (6.2–7.2) reported by Van Soest (1994) for optimal microbial activities. The ruminal ammonia-nitrogen concentration recorded in this study was similar to the range of 9–23.4 mg dL^{-1} (Woyengo *et al.*, 2004) and 4-25 mg dL^{-1} (Erdman *et al.*, 1986). Concentration of ruminal ammonia-nitrogen depends on the level and degradability of nitrogen in the ingested feed, the rate of its incorporation into the microbial protein, the rate of passage from the rumen and absorption by the rumen wall (Oosting, 1993). The low ammonia-nitrogen concentration in MS+G fed group may be due to low digestibility and crude protein content of the diet. Ammonia nitrogen is crucial to microorganisms in the rumen for the synthesis of microbial proteins, which are needed to meet the maintenance requirement of ruminants. Also, sufficient dietary nitrogen maximizes bacterial fermentation, energy digestibility and intake in ruminant.

The higher total volatile fatty acids observed in all animals fed treated maize stover could be attributed to increased nutrient content and digestibility of these treatments with values within the normal range of 70–150 mmol L^{-1} as reported by McDonald *et al.* (1996). Meanwhile, factors such as production rate, absorption across the rumen wall and utilisation by microorganisms had been stated to affect concentration of volatile fatty acids in the rumen (Van Soest, 1994). Volatile fatty acids production is important to ruminants as they provide over 70 % of the ruminant's energy supply.

A readily available feed resource, *Gmelina arborea* can be used by livestock owners as a cheap protein supplement to ruminants fed low quality roughage like maize stover to improve their intake, digestibility and hence, better their performance. Therefore, the present study encourages the feeding of UMT+G to goats by farmers during the dry season: feeding UMT+G led to a 29 % increase in DMI that resulted in a 42 % improvement in dry matter digestibility and 60 % nitrogen retained when compared with that of MS+G. All these will in turn increase the overall performance of the animals.

5 Conclusions

The findings of this study showed that treatment of maize stover with urea, molasses and urea molasses improved its nutrient composition in terms of increased crude protein and decreased NDF, ADF and ADL. Feeding of the treated stover with *Gmelina arborea* supplementation especially UMT+G enhanced the intake, digestibility, nitrogen balance and rumen fermentation parameters of West African dwarf goats. *Gmelina arborea* is readily available and high in nutritive values, which is needed for optimum growth and production of small ruminants. In addition, the technology involved in the treatment of maize stover with urea and molasses (UMT) as explained in this study is simple and can easily be carried out by small-scale ruminant owners. Therefore, UMT with *Gmelina arborea* supplementation is a considerable option for better utilisation of maize stover.

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Conflict of interest

The authors declare that they have no conflict of interest.

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