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Mineral balance, nutrient intake and digestibility of West African dwarf (Wad) goats fed urea-mixed milled maize stover diets

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Abstract

Twelve (12) male West African dwarf (WAD)goats with an average weight of 8.5 kg were monitored in a completely randomized design, to determine the nutrient intake, digestibility and mineral balance when fed urea-mixed milled maize stover (UMMS) diets in the dry season. Four dietsD1, D2, D3 and D4 containing 0, 3, 4.5 and 6% inclusion levels of urea respectively and 60% maize stovers each were fed to the goats during 14 weeks feeding experiment, for digestibility trials, weighed feed was fed each day for 7 days after an initial 14 day adaptation period, urine, faecal and diet samples were collected and analysed. Results showed that crude protein (CP) content of diets increased as the inclusion level of urea increases while voluntary dry matter intake (DMI) of all nutrients by bucks, decreased significantly (P<0.05) with the increase in dietary urea. There were significant differences (P<0.05) in the apparent digestibility of crude fibre (CF) and nitrogen free extract (NFE) of diets but all other nutrients showed no significant variation (P>0.05) in digestibility. Mineral intake by bucks decreased significantly (P<0.05) with increasing level of dietary urea inclusion. The highest value of mineral retention was recorded for goats on diet D1. The inadequacy of some minerals in experimental diets may require supplementation when a urea-mixed milled maize stover (UMMS) diet is fed to goats during the dry season.

Keywords: *Goats; urea; milled maize stover; mineral balance; digestibility*

Introduction

Animal protein intake in Nigeria and the economy of small holder farmers can be considerably improved with goat production. Small scale livestock farmers, especially women can engage in goat production at a relatively small cost by feeding common, abundantly available crop residues. The seasonality of feedstuff has been highlighted as constraints to goat production in Nigeria, (Chukwuka, *et al*, 2010).

Earlier report (Onyeonagu and Njoku 2010) showed that yearly crop residues produced in large quantities in Nigeria are often wasted. The use of cereal crop residue is however limited due to poor quality of the roughage. It was observed that crop residues fed to WAD goats resulted in the maintenance of body requirement and optimal productivity levels (Kalio and Anyanwu 2016). It was also observed that mechanical techniques for forage processing may increase fiber utilization by reducing forage particle size, thereby increasing feed intake, gut fill and forage surface area for microbial actions (Adesogan et al, 2019). Jabbar *et al*. (2009) reported that fertilizer grade urea is suitable for the treatment of crop residue and many studies (Barde *et al.*, 2010; Elias and Fulpagare, 2015; Ngu *et al.*, 2019; Patra and Aschnebach, 2018) had been carried out on the use of urea treatment to improve the feeding quality of maize stovers for ruminants. There have been contrasting reports on the effect of urea ammoniation on performance of ruminants. Reed *et al.* (2017) reported that inclusion of urea into ruminant diets produced a slightly negative effect on energy intake, dry matter intakes and there was less efficient utilization of Nitrogen from urea, leading to the lower gains. Oliveira *et al.* (2016) however reported that urea acts beneficially on fibrous forages when ensiled with urea.

For optimum production, health status, and physiological functions, minerals are needed in the diet of goats (Goff, 2018); however, mineral bioavailability and balance are more important than how much is ingested (Mamiro et al, 2016). There is limited data on the effect of feeding low-quality feedstuffs on mineral nutrient intake by goats;therefore, this research was carried out to evaluate the nutritive value of urea-mixed milled maize stover (UMMS) diets fed to West African dwarf (WAD) bucks as dry season feed.

Materials and methods

Experimental animals

Twelve (12) WAD goats weighing between 7 and 10kg were quarantined for 4 weeks and acclimatized to the experimental diet for 2 weeks. The study was conducted in the small ruminant unit of the Teaching and Research Farm, Federal University of Agriculture, Abeokuta.

Experimental diets

Maize stovers (MS) were cut into 2-3cm sizes, sun-dried, milled and kept in a well-ventilated room. Elephant grass (basal feed) was harvested every evening and wilted, before being fed to animals the following morning, to enhance daily intake of the fresh grass. Four experimental diets tagged D1, D2, D3 and D4 containing 0, 3, 4.5 and 6% urea inclusion levels respectively and 60% by weight of MS each was formulated with urea included at 0, 30, 45, and 60g /kgDM. Animals were randomly selected into four diet groups containing three replicates each. Feed was offered based on 5% body weight and feeding trial lasted for 14 weeks. Goats were fed the weighed experimental diets every morning at 08:00hrs throughout the experimental period. Voluntary intake was determined as the difference between feed offered and feed refusal was weighed daily to estimate intake.

Digestibility trials were monitored by transferring each goat into individual metabolic cage with an adaptation period of 14 days before data collection commenced. Digestibility study was done as described by McDonald et al, (1987). The loss of nitrogen from urine by volatilization was prevented by rinsing urine bottle with 10%H_2SO_4 and stored in the freezer till required for analysis.

Chemical analysis

The proximate compositions of the experimental feed, faecal and urine samples were determined as described by AOAC (2012). The neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin in both feed and faecal samples were determined by methods of (Van Soest & Robertson, 1985). The gross energy of the experimental diets was determined with an adiabatic bomb calorimeter. Mineral analysis was by wet digestion of samples in HNO_3/$HCLO_3$ and concentration of calcium (Ca), phosphorus (P) and magnesium (Mg) were obtained with atomic absorption spectrophotometer (Bulk Scientific Model 2000, East Norwalk, U.S.A), while sodium (Na) and potassium (K) were determined by flame photometer.

Statistical analysis

Data were analysed using the one-way analysis variance (ANOVA) in a completely randomized design with the statistical package SPSS (version 17). Means were separated where necessary using Duncan's Multiple Range Test.The result of the analysis was used for apparent digestibility and mineral retention determination.

Results and Discussion

Chemical composition of diets

The chemical composition of milled maize stover (MS) and fresh elephant grass (EG) (Table1) showed dry matter (DM), crude protein (CP) and crude fibre (CF) of milled MS were higher ($p<0.05$) than found in fresh EG. The DM value for the MS(89.67g/100g) is similar to values reported by (Woyengo, *et al*, 2004), but higher than reported values by Silva et al. (2008) and Amuda et al. (2017), but lower than values reported by Li et al. (2014); Elias and Fulpigare, (2015),for MS fed to ruminants.The CP value (8.95g/100g) for MS is comparable to values reported in earlier studies (Amuda et al., 2017; Silva et al., 2008; Woyengo et al., 2004;), but higher than CP values reported by Li et al. (2014) and Elias & Fulpigare, (2015). CF value (29.79 g/100g) of the MS is lower than that reported from studies by Amuda et al., (2017); Elias and Fulpigare, (2015).The fibre fractions,in the milled MS, had higher ($p<0.05$) values than in fresh EG. Neutral detergent fibre (NDF)was lower than values from the findings of Amuda et al., (2017); Li et al. (2014) while the acid detergent fibre (ADF) was higher than that reported by the same authors. The gross energy in milled MS (2.380 Kcal/kg) was higher ($p<0.05$) than (1.247Kcal/kg) value obtained in fresh EG. This implies that milled MS has considerable potential nutrients to meet the nutritional needs of goats.

Mineral nutrient composition of sundried milled MS and wilted elephant grass (Table1) revealed that calcium (Ca), sodium (Na) and potassium (K) content of maize stover had higher values than that reported by Li *et al*. (2014), but were lower in value than previous study (Lengarite *et al*., 2013). However, Mg content in the maize stover used was similar to values reported by Lengarite *et al*. (2013), the observed differences in mineral contents may be due to maize crop varieties. Geleti *et al*. (2011) suggested that selection should be made for maize crop variety with high yield and desirable crop residues qualities. The Na content of *Pennisetum purpureum* had higher values while the Mg and P contents of the grass forage were within the range of values reported by Little *et al*. (1989). The K and Ca contents were however lower than reported values by Herrera *et al.*, 2008 for *Pennisetum purpureum*. The differences in values of grass forage mineral content may be due to the environment, soil in which the forage was grown and/or species (Lee, 2018).

The chemical composition of the experimental diets fed to the WAD goats (Table 2)shows that the CP content ranged from 16.98%-17.85%, implying that the CP content of the diets was adequate for the bucks since they were higher than values (11% to 13%) recommended by Luginbuhl (2015) for tropical sheep and goats. The CP increased with an increase in the level of urea in the diets showing that urea inclusion in MS diets improved the CP content of MS. This result corroborates the findings of Woyengo *et al*, (2004); Elias and Fulpigare, (2015); that urea treated MS recorded higher CP content. The CF content (34.11% in D4-33.86% in D1) is higher than values reported by Despal *et al*, (2017) but lower than that reported by Elias & Fulpigare, (2015). This variation may be a result of the high Lignin content of the MS used. Microbial activities on feed particles ensure effective degradation of the forage fibre (Leng 2014) and ruminants cope with diets of fibrous forages such that it does not utilize low-fibre diet as efficiently (Devant *et al.*, 2016).

Table 1: Comparative nutrient composition (g/100g DM) of feeds tufffed to the WAD goats

Components	DMMS	*PP* (fresh)	t values	Level of significance
Dry matter	89.67	39.24	617.64	0.00
Crude protein	8.95	6.24	33.19	0.00
Crude fibre	29.79	18.24	141.46	0.00
Acid detergent fibre	71.61	19.96	632.58	0.00
Neutral detergent fibre	46.34	41.16	63.44	0.00
Acid detergent lignin	13.40	6.12	89.16	0.00
Cellulose	33.24	13.84	237.60	0.00
Hemicellulose	24.77	21.20	43.72	0.00
Ether extract	1.96	0.86	13.47	0.00
Ash	8.75	5.97	34.05	0.00
Nitrogen free extract	50.55	68.69	222.17	0.00
Sodium	0.7	1.23	6.49	0.00
Potassium	0.27	0.39	1.47	0.22
Calcium	0.55	0.17	4.65	0.01
Magnesium	0.29	0.39	1.23	0.29
Phosphorus	0.16	0.11	0.61	0.57
Nitrogen	1.43	1.02	5.02	0.01
Gross Energy (kcal/kgD)	2.380	1.247	13.84	0.00

DMMS–Dried milled maize stover, PP–*Pennisetum purpureum*,

Nutrient intake

The nutrient intakes of the WAD goats (Table 3) show significant differences (P<0.05) among the treatment groups for the intake of all nutrients, however, goats on D1 had the highest DM intake (296.19gd^{-1}) while goats on D4 had the lowest DM intake (196.63gd^{-1}).Wang *et al.* (2016) reported that DM intake decreased as the level of urea supplementation increased, as obtained in this study, and similar trends were recorded for other nutrients intake. The fiber fraction intakes of the four diets showed significant differences (P<0.05) among treatments with D1 having the highest intake of fiber fraction. ADF and ADL intakes ranged from 99.00-135.40and 33.95-47.30gd^{-1} respectively, these values were comparable to earlier reports for growing goats (Ndemanisho *et al.*, 2007), but lower than values for sheep fed urea-molasses treated MS diets (Abera *et al.*, 2018).

Table 2. Percentage and Proximate composition (g/100g DM) of UMS diets fed to the WAD goats

Components	D1	D 2	D 3	D4
Maize stover	60.00	60.00	60.00	60.00
Wheat offal	30.00	25.00	22.50	20.00
Palm kernel meal	5.00	5.00	5.00	5.00
Urea	0.00	5.00	7,50	10.00
Salt	3.00	3.00	3.00	3.00
Bone meal	1.50	1,50	1.50	1.50
Sulphur	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00
Proximate composition				
Dry matter	89.87	90.03	89.91	90.08
Crude protein	16.98	17.33	17.50	17.85
Crude fibre	33.86	34.03	33.97	34.11
Acid detergent fibre	38.84	39.26	40.34	39.96
Neutral detergent fibre	59.78	60.15	61.67	61.29
Acid detergent lignin	13.86	13.97	14.13	14.08
Cellulose	24.94	25.29	26.21	25.88
Hemicellulose	20.94	20.89	21.33	21.33
Ether extract	3.59	3.67	3.78	3.73
Ash	8.29	8.34	8.49	8.43
Nitrogen free extract	37.28	36.63	36.26	35.88
Gross Energy (kcal/kgDM)	3.987	3.994	3.979	3.968

D1= Diet1 containing 0% urea, D2 = Diet2 containing 3% urea,
D3= Diet3 containing 4.5% urea, D4 = Diet4 containing 6% urea

Table 3: Nutrient intakes of the West African dwarf goats fed experimental diets ($gd^{-1}W^{0.75}$)

Average nutrient intake/ animal	D1	D2	D3	D4	SEM
Dry Matter	296.19^{a}	238.95^{b}	218.98^{b}	196.63^{b}	13.38
Crude Protein	50.29^{a}	41.41^{ab}	38.32^{b}	35.10^{b}	2.12
Crude Fibre	100.29^{a}	81.31^{ab}	74.39^{b}	67.07^{b}	4.49
Ether Extract	10.63^{a}	8.77^{ab}	8.28^{b}	7.33^{b}	0.45
Ash	24.55^{a}	19.92^{ab}	18.85^{b}	16.58^{b}	1.08
NitrogenFree Extract	110.42^{a}	87.53^{b}	79.40^{b}	70.55^{b}	5.25
Neutral Detergent Fibre	177.0^{a}	143.73^{ab}	135.05^{b}	120.52^{b}	7.68
Acid Detergent Fibre	115.04^{a}	93.79^{ab}	88.34^{b}	78.57^{b}	4.95
Acid Detergent Lignin	41.06^{a}	33.37^{ab}	30.94^{b}	27.69^{b}	1.81
Cellulose	73.87^{a}	60.43^{ab}	57.39^{b}	50.89^{b}	3.13
Hemicellulose	62.02^{a}	49.92^{ab}	46.71^{b}	41.94^{b}	2.72
Gross Energy	11.81^{a}	9.55^{b}	8.71^{b}	7.80^{b}	0.54

a, b – Means on the same row having different superscripts are significant ($P< 0.05$).
D1= Diet1 containing 0% urea, D2 = Diet 2 containing 3% urea,
D3= Diet 3 containing 4.5% urea, D4 = Diet 4 containing 6% urea
SEM – standard error of mean

Digestibility

The digestibility of CF and NFE varied significantly (P<0.05) among the dietary treatments (Table 4) with CF values ranging from 66.17% - 76.78%, while NFE values ranged from 40.79% - 64.12%. The inclusion of increasing levels of urea into the MS diet resulted in better digestibility values of DM, CP, CF, NDF, ADF, ADL, cellulose and hemicellulose. The DM digestibility of nutrients in the present study is higher than values reported by Elias & Fulpigare, (2015); Mubi *et al.* (2008) who reported improved DM digestibility of stover treated with urea. Treatments of crop residue with alkali helps in the dissolution of acid and neutral detergent fibre content of the crop residue. Alkali treatment results in cell wall size increase and as enzyme's actions are activated, bonds between cell wall carbohydrates and lignin are broken thereby increasing the rate of carbohydrate degradation by microbes in the rumen and making hemicellulose and CP more soluble (Adesogan *et al.*, 2019). The CP digestibility values ranged from 59.75-70.02%, CP digestibility of the present study agrees with Yadete (2014) who reported that ammoniation increase DM, Nitrogen, and energy digestibility in straws. khattab *et al.* (2013) also reported that DM, OM, CP, digestibility tends to increase with an increasing level of N from urea in diets.

Table 4:Digestibility of nutrients by the West African dwarf goats fed experimental diets

Parameters	D1	D2	D3	D4	SEM
Dry matter	54.25	56.20	54.48	70.29	2.55
Crude protein	63.20	63.07	59.75	70.02	2.08
Crude fibre	**66.53**[ab]	**66.17**[b]	**68.00**[ab]	**76.78**[a]	1.64
Ether Extract	75.76	75.57	72.86	82.34	1.43
Ash	61.93	62.97	62.65	74.63	2.10
Nitrogen Free Extract	**40.79**[b]	**45.52**[ab]	**43.71**[b]	**64.12**[a]	3.31
Neutral Detergent Fibre	65.09	64.34	66.31	74.98	1.80
Acid Detergent Fibre	65.25	65.14	66.20	75.94	1.84
Acid Detergent Lignin	**60.36**[ab]	**59.95** [ab]	**55.05**[b]	**69.99**[a]	2.18
Cellulose	67.58	66.68	71.08	76.84	1.67
Hemicellulose	65.53	66.39	66.03	77.48	1.91
Digestible Energy	81.96	82.08	80.65	87.01	1.02

a, b – Means on the same row having different superscripts aresignificant (P< 0.05).
D1= Diet1 containing 0% urea, D2 = Diet 2 containing 3% urea,
D3= Diet 3 containing 4.5% urea, D4 = Diet 4 containing 6% urea
SEM –-standard error of mean.

Mineral balance

The mineral balance of the WAD (Table5) shows differences (P<0.05) among the treatments in terms of K, Ca, Mg and P intakes. Na intake from all diets was above the recommendation of 0.8-1.0g/Kg DM (NRC 1985), indicating that goats met their Na requirements from experimental diets. Na intake by bucks in the study was greater than earlier reports (Lengarite *et al.*, 2013; Ribeiro *et al.*, 2018). Ca and P intakes from the experimental feeds were lower than the recommendations of NRC (1985) for goats suggesting the need for supplementation of Ca and P when the UMMS diet is fed to goats. The pattern of Ca utilization for all diets in the study is better than negative values of Ca balance and retention reported by Bamikole and Babayemi (2009). Mg intake is within range while K intake was lower than reported values (Kessler, 1991; NRC, 1985). The better utilization of Mg agrees with the report of

Bamikole and Babayemi, (2009). High Mg intake may be due to the low K intake since reports reports (Schonewille *et al.*, 1999) showed that a high intake of K depresses the absorption of Mg in cows. Report by Underwood and Suttle (1999) revealed that decreasing K intake by 1g/kg DM resulted in a 0.52 % increase in Mg absorption. Low intake of potassium across the dietary treatment may lead to inadequate energy metabolism since an imbalance in the intake of Na and K can result in inhibition of ATP (which depends on Na+ - K+ pump) and metabolism of energy in animals.

Table 5: Mineral balance of the WAD goats fed the experimental diets (g\day).

Parameters	DI	DII	DIII	DIV	SEM
Sodium (Na)					
Na intake	2.23	2.19	2.06	2.11	0.04
Faecal Na output	0.20^{b}	0.24^{a}	0.13^{c}	0.16^{bc}	0.01
Urinary Na output	0.03^{b}	0.03^{b}	0.03^{b}	0.04^{a}	0.00
Total Na output	$\mathbf{0.23^{b}}$	$\mathbf{0.28^{a}}$	$\mathbf{0.17^{c}}$	$\mathbf{0.20^{bc}}$	**0.01**
Na Retained	2.00	1.91	1.89	1.91	0.04
Na Retention %	89.62^{ab}	87.33^{b}	91.87^{a}	90.75^{a}	0.57
Calcium (Ca)					
Ca intake	$1.\ 22^{a}$	0.92^{b}	0.92^{b}	0.90^{b}	0.05
Faecal Ca output	0.75^{a}	0.74^{a}	0.69^{a}	0.45^{b}	0.04
Urinary Ca output	0.06	0.06	0.06	0.06	0.00
Total Ca output	$\mathbf{0.81^{a}}$	$\mathbf{0.80^{a}}$	$\mathbf{0.75^{a}}$	$\mathbf{0.51^{b}}$	**0.04**
Ca Retained	0.41^{a}	0.12^{b}	0.17^{b}	0.39^{a}	0.05
Ca Retention %	66.39^{bc}	86.96^{a}	81.52^{b}	56.67^{c}	4.17
Phosphorus (P)					
P intake	$1.\ 27^{a}$	1.26^{a}	0.91^{b}	1.15^{a}	0.05
Faecal P output	0.27^{a}	0.29^{a}	0.18^{b}	0.21^{b}	0.01
Urinary P output	0.03	0.03	0.03	0.03	0.00
Total P output	$\mathbf{0.30^{a}}$	$\mathbf{0.32^{a}}$	$\mathbf{0.21^{b}}$	$\mathbf{0.24^{b}}$	**0.01**
P Retained	0.98	0.95	0.70	0.91	0.05
P Retention %	76.25	74.93	77.22	78.98	0.96
Magnesium (Mg)					
Mg intake	$1.\ 79^{a}$	1.48^{ab}	1.53^{ab}	1.34^{b}	0.06
Faecal Mg output	0.39^{ab}	0.30^{bc}	0.41^{a}	0.23^{c}	0.02
Urinary Mg output	0.04^{b}	0.05^{b}	0.04^{b}	0.31^{a}	0.05
Total Mg output	**0.44**	**0.35**	**0.46**	**0.55**	**0.04**
Mg Retained	1.36^{a}	1.14^{ab}	1.07^{ab}	0.79^{b}	0.08
Mg Retention%	75.11	76.73	69.94	59.11	3.10
Potassium (K)					
K intake	2.08^{a}	1.91^{ab}	$1.\ 69^{b}$	1.67^{b}	0.06
Faecal K output	0.29^{a}	0.32^{a}	0.26^{ab}	0.21^{b}	0.01
Urinary K output	0.04	0.04	0.04	0.04	0.00
Total K output	$\mathbf{0.33^{a}}$	$\mathbf{0.36^{a}}$	$\mathbf{0.30^{ab}}$	$\mathbf{0.25^{b}}$	**0.01**
K Retained	1.75	1.55	1.39	1.42	0.06
K Retention %	83.95	81.37	82.11	84.80	0.72

a, b, c –Means on the same row having different superscripts are significant ($P<0.05$).
D1= Diet1 containing 0% urea, D2 = Diet2 containing 3% urea,
D3= Diet3 containing 4.5% urea, D4 = Diet4 containing 6% urea

Conclusions and Recommendation

It can be concluded from the experiment that incorporation of urea into maize stover without adequate moisture may not to be effective, since the use of urea in the improvement of crop residues requires sufficient moisture for efficacy. Milling of the maize stover to reduce forage particle size, increased gut fill and thereby increasing intake, was effective for bucks fed diet D1 by increasing the intake but not for bucks fed diets D2 to D4 where intake decreases as the level of urea inclusion in the diet increases. This decrease may be as a result of taste and/or palatability, preference and/or acceptability by goats, therefore, improving taste may enhance acceptability and intake. The reduced rate of nutrient intake may also be partially due to the slightly negative effect of increasing levels of urea in the diets. Goats should be supplied with salt licks for Ca, P, Mg and K supplementation when UMMS is fed since the intake of these nutrients by goats was shown to be inadequate. In maize crop breeding, selection should be made for maize crop variety with both high yield and desirable crop residue qualities so that the nutrient requirement of ruminants feeding on these residues may be met.

Conflict of interest

The authors declare no conflict of interest.

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