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Utilization of *Moringa oleifera* Fodder Combinations with *Leucaena leucocephala* and *Gliricidia sepium* Fodders by West African Dwarf Goats

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ABSTRACT

Unlike Leucaena (LEU) and Gliricidia (GLI) fodders and in spite of its globally acclaimed nutritive values, Moringa (MO) fodder is yet to receive adequate research attention in Nigeria as a protein supplement for ruminants. The nutritional synergies between equal but separate combinations of MO with LEU and GLI fodders, respectively, relative to a sole MO fodder were evaluated with West African Dwarf (WAD) goats. Three male WAD goats, weighing 10±1 kg, were used in a feed intake and nutrient digestibility study consisting of three experimental periods of 24 days each. Three experimental diets; 50 MO:50 LEU, 50 MO:50 GLI and 100 MO were investigated using a 3*3 Latin Square within a complete randomized design. Performance indices were Dry Matter Intake (DMI), nutrient digestibility, nitrogen utilization and Relative Feed Value (RFVs). DMI and nutrient digestibility values were high with no ($p>0.05$) diet effects. Nitrogen in the three diets was well utilized. It was however better ($p<0.05$) utilized in 100 MO with minimal losses in faeces (5.47%) and urine (14.15%), leading to better nitrogen balance and retention. RFVs were generally high but significantly ($p<0.05$) highest for 100 MO. Based on the RFVs, 50 MO:50 LEU and 50 MO:50 GLI fodder combinations appeared promising as protein supplements for WAD goats, with a better prospect of utilization of 50 MO:50 GLI based on nitrogen utilization. The fodder combination will also allow for an optimal utilization of the available moringa fodder as its availability is still limited in Nigeria.

Key words: Dry matter intake, nutrient digestibility, nitrogen utilization, relative feed value, WAD goats

INTRODUCTION

It is well known that forages have an important role in ruminant nutrition in terms of providing energy, protein and minerals as well as fibre for chewing and rumination (Ahmad *et al*., 2000; Ranjbar, 2007). However, a major constraint to livestock production in tropical Africa is the scarcity and fluctuating quality of year round forage supply (Ajayi *et al*., 2005). Most available ruminant feeds/ feedstuffs during the dry season have been described as fibrous; resulting in low digestibility and poor livestock production (Richard *et al*., 1994). Research efforts (Benninson and Paterson, 2003; Dzowela *et al.*, 1997; McDonald *et al.*, 1998) have confirmed the potency of using browse plants for ruminant nutrition in the tropics. Their use as supplements has been shown to enhance intake of poor quality roughages, improve growth rates and increase reproduction efficiency in ruminants (Karachi and Zengo, 1997; Alayon *et al.*, 1998; Orden *et al.*, 2000). The high dry matter degradability values of the leaf meals make them appropriate as supplements with basal diets of poor quality (Ndemanisho *et al.*, 1998). However, despite the fact that the list of such browse trees and shrubs with potential use as fodder comprises more than 300 species, research has unfortunately concentrated on a few (Rosales and Gill, 1997; Anurudu *et al.*, 2004).

In Nigeria, the leaves of *Leucaena leucocephala* (LEU) and *Gliricidia sepium* (GLI) plants have enjoyed a lot of research attention for all classes of livestock (Odeyinka *et al.*, 2003; Asaolu and Odeyinka, 2006; Amata and Bratte, 2008) for almost three decades now. Supplementation of goats' nutrition through the use of browse species such as GLI and LEU which contain more crude protein compared to tropical grasses, crop residues and agro-industrial by-products have been reported (Odeyinka *et al.*, 2003; Asaolu and Odeyinka, 2006). Ademosun *et al.* (1998) reported that *Gliricidia sepium* and *Leucaena leucocephala* have been successfully used for small ruminant production systems in alley farming and intensive feed gardens. The leaves of *Moringa oleifera* (MO) are gradually gaining research attention within the West African sub-region as animal feed supplements to address the observed crude protein shortages of natural pastures and crop residues (Nouala *et al.*, 2006; Asaolu *et al.*, 2009a, b, 2010). MO leaves, along with other ingredients, are used in the northern part of Nigeria to make cold salad (Dambu) for human consumption. Unfortunately, Odeyinka *et al.* (2007) observed that many of the farmers in the south western part of Nigeria were ignorant of the plant, that is, they could neither identify the plant physically nor by name. However, efforts are currently being made to bring the plant to national consciousness through fora such as the First National Summit on *Moringa* Development organized by the Raw Materials Research and Development Council at the federal capital of Abuja in October, 2010.

Moringa oleifera Lamarck, originally from India, is widely distributed in many tropical regions; in the Pacific region (Aregheore, 2002), in West Africa (Freiberger *et al.*, 1998; Cassius *et al.*, 2000), as well as Central America and the Caribbean (Ramachandran *et al.*, 1980; Foidl *et al.*, 1999). It is a non-leguminous multipurpose tree and is one of the fastest growing trees in the world with a high crude protein in the leaves and negligible contents of anti-nutritive compounds (Makkar and Becker, 1996) *Moringa* is known to offer an alternative source of protein to ruminants wherever it thrives (Nouala *et al.*, 2006). It is noteworthy that MO, GLI and LEU leaves have comparable protein contents (21-25%), (Abdulrazak *et al.*, 2006; Asaolu *et al.*, 2010). However, the crude protein of *Moringa* is of better quality for ruminants than the crude protein of leaves of *Gliricidia* or *Leucaena* because of its high content of bypass protein, 47% versus 30 and 41%, respectively (Becker, 1995). *Moringa* is also rich in carotene, ascorbic acid, iron and in the two amino acids generally deficient in other feeds i.e., methionine and cystine (Makkar and Becker, 1996). The metabolizable energy for *Moringa* fodder has been reported by researchers to be of a similar order of magnitude as for some highly nutritive fresh forages (Foidl *et al.*, 2001; Asaolu *et al.*, 2009a) such as alfalfa. Alfalfa forage at the pre-bloom stage was reported by Close and Menke (1986) to have a metabolizable energy content of 10.0 MJ kg^{-1}DM.

In view of the just emerging importance of *Moringa* as a browse species at the national level, research efforts at optimizing its utilization alongside the currently commonly utilized browse species become pertinent. There is, however, a dearth of information on the synergies between *Moringa*, *Leucaena* and *Gliricidia* species as protein supplements for ruminants. Nutritive values of forages depend on nutrient concentration, availability of these nutrients to animals and the effect of feed composition on the voluntary intake of the feed (Heydari *et al.*, 2006). Hence, the performance of WAD goats on equal but separate combinations of MO with LEU and GLI fodders respectively, relative to a sole MO fodder was evaluated. Performance indices were dry matter intake, nutrient digestibility, nitrogen utilization and relative feed values.

MATERIALS AND METHODS

Experimental site: The study was conducted at the Teaching and Research Farm of the Ladoke Akintola University of Technology, Ogbomoso, Oyo State, in the south western part of Nigeria. Ogbomoso is in the derived Savanna zone and situated at about 600 m above sea level and located on latitudes 8° 07' N and 8° 12' N and longitudes 4° 04' and 4° 15' E (Oguntoyinbo, 1978). Ogbomoso has a maximum temperature of 33°C and a minimum temperature of 28°C. The humidity of the area is high (74%) all year round except in January when the dry wind blows from the north and the annual rainfall is over 1000 mm (Olaniyi, 2006).

Forage materials: MO, LEU and GLI leaves were harvested from existing plantations at the Teaching and Research Farm after a cut-back period of 60 days in March 2010; the peak of the dry season. The leaves of each of the three browses were pooled together separately and air-dried to constant moisture levels and thereafter bagged separately for later use.

Animals, experimental design and management: Three male West Africa Dwarf (WAD) goats, weighing 10±1 kg, were used for this study in a 3*3 Latin Square within a complete randomized design with three treatments and three experimental periods of 24 days each. Two consecutive periods were separated by 7 days animal rest. During the rest periods, the goats were fed freshly-harvested *Panicum maximum*, *Gliricidia sepium* and dried cassava peels. The animals were purchased from a local small ruminant market in Ogbomoso. These animals were quarantined for three weeks prior to the commencement of the study. During this period, they were treated with oxytetracycline antibiotic injection for three days, drenched with Amprolium against coccidia, administered Ivermectin against ecto-parasites and gastrointestinal nematodes and vaccinated against *pestes des petit ruminant* (PPR). During this period, the animals were fed freshly-harvested *Panicum maximum, Gliricidia sepium* and dried cassava peels. The animals were thereafter housed in individual metabolic cages designed for the complete separation of faeces and urine and were adapted for an initial period of 7 days. The adaptation period was followed by 10 days of feed intake measurements and 7 days of faecal and urine collection phase consecutively. The animals were provided with access to mineral-salt lick and fresh clean water through the duration of the experiment.

There were three dietary treatments, namely:

- 100% Moringa (100 MO)
- 50% Moringa+50% Gliricidia (50 MO:50 GLI) and
- 50% Moringa+50% Leucaena leaves (50 MO:50 LEU)

During the feed intake measurement phase, feed refusals were collected each day and weighed to assess intake before any new feed was offered. The animals were fed at 4% of body weight (dry matter basis) while the animals were restricted to 90% of their average dry matter intake during the faecal collection phase to minimize/eliminate feed refusal. Previously air-dried leaves were used in preparing the experimental diets and foliage combinations were thoroughly mixed manually to minimize/eliminate animal preference/selection.

During the urine and faecal collection phase, urine and faeces voided by each animal were collected and measured between 08.00 and 09.00 h before morning feeding. A dustpan and brush were used to collect faeces each morning before feeding. Total daily faecal output for each goat was weighed before 10% of daily faecal output by each animal was taken for dry matter determination. Faeces were bulked separately for each goat during each period; milled with a simple laboratory mill and stored in airtight bottles until required for further analysis. The urine from each animal was collected in 5 mL of 5% H_2SO and measured. Ten percent aliquot solution was taken daily frozen until needed for nitrogen analysis. One hundred gram samples of experimental forages were taken daily during the collection period and analyzed for dry matter by drying at 70°C for 24 h and stored at ambient temperature for later analysis for proximate constituents. Samples of daily feed refusals were also analyzed for their proximate contents.

Chemical analysis: At the end of the experiment, stored forages, refusals and faecal samples were pooled together and separately re-dried to constant weight, ground using a simple laboratory mill and subsequently analyzed for the proximate contents using the standard methods of AOAC (2000) The ADF and NDF fibre contents of the experimental forages were determined by the methods of Van Soest *et al.* (1991). The urine samples for each animal were pooled together, defrosted and analyzed for nitrogen contents also the standard method of AOAC (2000). For mineral analysis, samples were dry-ashed at 600°C for 4 h, followed by wet digestion of the resulting ash. Ca, Na, Mg, P, Mn, Zn, Cu and Fe levels were measured with an atomic absorption spectrophotometer while K was determined using a flame photometer. The nutrient and mineral compositions of the mixed fodder diets were computed from the values obtained for the single fodders.

Statistical analysis: The data on the animal performance indices were subjected to analysis of variance using the General Linear Model of SAS (1998). Significant differences between means were separated using the Duncan's New Multiple Range Test (DNMRT) of the same package.

RESULTS

Nutrient and mineral compositions of the experimental fodders/fodder combinations: The nutrient compositions of the experimental fodders, singly and in the investigated combinations, are as shown in Table 1. Crude protein concentrations of the fodders ranged from 21.64 g/100 g for the sole *Gliricidia* fodder to 28.86 g/100 g for the sole *Leucaena* fodder. As for the fibre components, the NDF varied between 26.35 g/100 g for the sole *Moringa* fodder to 29.60 g/100 g for the sole *Gliricidia* fodder while the ADF was in the range of 40.40 g/100 g for the sole moringa fodder to 42.80 g/100 g for the sole leucaena fodder. All the fodders, singly and in combinations, were high in organic matter with values around 90 g/100 g. The macro-mineral levels of the experimental fodders/fodder combinations were compared to the critical levels recommended by McDowell (1985) to cover the requirements of ruminants as well as diet requirements by goats (Table 1). All the macro-mineral levels, except P in the sole *Leucaena* and sole *Gliricidia* fodders which was at the borderline (0.24; 0.25 g/100 g DM), were higher than the recommended critical levels. Among the sole fodders, only *Moringa* contained Na at a level (0.20 g/100 g DM) higher than the 0.07 g/100 g DM required in the diet of goats. However, it was observed that combinations of

Table 1: Nutrient and mineral compositions of experimental fodders/fodder combinations fed to West African Dwarf goats

	Fodders/fodder combinations				
Composition	MO	LEU	GLI	*50 MO: 50 LEU	*50 MO: 50 GLI
Nutrients (g/100 g)					
DM	95.57	94.38	95.86	94.98	95.72
CP	26.74	28.86	21.64	27.80	24.19
EE	8.06	5.67	4.55	6.87	6.31
CF	11.03	12.16	10.70	11.60	10.87
NDF	26.35	29.21	29.60	27.78	27.98
ADF	40.40	42.80	42.50	41.60	41.45
OM	89.83	92.54	91.54	91.18	90.68
NFE	39.57	59.67	49.49	49.62	44.53
Macro-minerals (g/100 g)					
Ca (0.30**)	1.10	1.62	0.57	1.36	0.84
P (0.25**)	0.43	0.24	0.25	0.34	0.34
Na (0.07**)	0.20	0.05	0.04	0.13	0.12
K (0.20**)	1.50	0.25	1.80	0.88	1.65
Mg (0.20**)	0.50	1.20	0.35	0.85	0.43
Micro-minerals (mg kg^{-1})					
Fe	281.00	200.00	205.00	240.50	243.00
Mn	80.00	40.00	51.50	60.00	65.75
Cu	7.00	10.50	5.50	8.75	6.25
Zn	29.00	21.00	18.00	25.00	23.50

MO: *Moringa oleifera*, LEU: *Leucaena l eucocephala*, GLI: *Gliricidia sepium*, DM: Dry matter, CP: Crude protein, EE: Ether extract, CF: Crude fibre, NDF: Neutral detergent fibre, ADF: Acid detergent fibre, OM: Organic matter, NFE: Nitrogen free extract, Ca: Calcium, P: Phosphorus, Na: Sodium, K: Potassium, Mg: Magnesium, Fe: Iron, Mn: Manganese, Cu: Copper, Zn : Zinc, *Nutrient and mineral concentrations of mixed fodders were calculated, **Critical macro-mineral levels for goats (McDowell, 1985)

Moringa fodder with either of the two other fodders corrected for the observed shortfalls in macro-mineral levels. Among the micro-minerals, Fe was found in the highest concentrations (200-281 mg kg^{-1}) followed by Mn, Zn and Cu with values ranging from 51.50-80.00, 18.00-29.00 and 5.50-7.00 mg kg^{-1}, respectively. The highest concentrations of these micro-minerals were found in the sole moringa fodder. Cu and Zn were found in the least concentrations in the sole *Gliricidia* fodder while Fe and Mn were found in the least concentrations in the sole *Leucaena* fodder.

Intake, digestibility and relative feed value of experimental fodders/fodder combinations: There was no ($p>0.05$) diet effect on dry matter intake which ranged from 278.00 g/animal/day (49.47 g kg^{-1} 0.75) for animals on 50 MO:50 GLI to 288.50 g/animal/day (51.33 g kg^{-1} 0.75) for the animals on the sole moringa diet (Table 2). Furthermore, the apparent nutrient (DM, CP and OM) digestibility values were not ($p>0.05$) significantly different. Apparently higher values were however obtained in favour of the sole moringa fodder. The Relative Feed Value (RFV) was high for all the experimental diets and ranged from 188.73 for 50 MO:50 GLI to an unusually high 202.42 for the sole moringa fodder, going by the quality standards assigned by the Hay Marketing Task Force of American Forage and Grassland Council (Rohweder *et al*., 1978) for legume, grass and grass/legume mixtures.

Nitrogen utilization by WAD goats fed the experimental fodders/fodder combinations: Nitrogen utilization data by West African Dwarf goats fed a sole diet of *Moringa oleifera* foliage and in equal combinations with *Leucaena leucocephala* and *Gliricidia sepium* are as shown in

Table 2: Mean dry matter intake (g/animal/day), apparent digestibility (%) and relative feed value of a sole diet of *Moringa oleifera* and in equal combinations with *Leucaena leucocephala* and *Gliricidia sepium* leaves by West African Dwarf goats

	Experimental diets			
Item	100 MO	50 MO:50 LEU	50 MO:50 GLI	SEM
Feed intake (gDM/animal/day)				
Moringa	288.50	149.00 (52.20%)	154.00 (55.40%)	
Leucaena	-	136.50 (47.80%)	-	
Gliricidia	-	-	124.00 (44.60%)	
Total DMI (g/animal/day)	288.50^{a}	285.50^{a}	278.00^{a}	3.32
Total DMI (g/kg$^{0.75}$)	51.33^{a}	50.80^{a}	49.47^{a}	2.50
Apparent digestibility coefficient (%)				
DM	77.19^{a}	75.56^{a}	76.25^{a}	3.02
CP	89.35^{a}	84.24^{a}	83.88^{a}	2.53
OM	79.50^{a}	76.50^{a}	78.00^{a}	3.00
Estimated index of quality				
Relative feed value	202.42^{a}	189.66^{b}	188.73^{b}	4.50

Means in the same row with the same superscript are not statistically different (p<0.05), MO: *Moringa oleifera,* LEU: *Leucaena leucocephala,* GLI: *Gliricidia sepium,* DMI dry matter intake, DM: Dry matter, CP: Crude protein, OM: Organic matter, SEM: Standard error of the mean

Table 3: Mean nitrogen utilization by WAD goats fed a sole diet of *Moringa oleifera* and in equal combinations with *Leucaena leucocephala* and *Gliricidia sepium*

	Experimental diets			
Variables	100 MO	50 MO:50 LEU	50 MO:50 GLI	SEM
Nitrogen intake (g day^{-1})	7.49^{a}	7.88^{a}	6.48^{b}	0.55
Faecal nitrogen (g day^{-1})	0.41^{a}	0.64^{a}	0.57^{a}	0.04
Urinary nitrogen	1.06^{c}	2.50^{a}	1.72^{b}	0.78
Total nitrogen loss	1.47^{c}	3.14^{a}	2.29^{b}	0.78
Nitrogen balance	6.02^{a}	4.74^{b}	4.19^{b}	0.74
Nitrogen loss (as % of nitrogen intake)				
Faecal loss	5.47^{b}	8.12^{a}	8.79^{a}	0.65
Urinary loss	14.15^{c}	31.72^{a}	26.54^{b}	2.15
Total loss	19.62^{b}	39.84^{a}	35.33^{a}	2.50
Nitrogen retention (as % of nitrogen intake)	80.37^{a}	60.15^{b}	64.66^{b}	9.91

Means in the same row with the same superscript are not statistically different (p<0.05), MO: *Moringa oleifera,* LEU: *Leucaena leucocephala,* GLI: *Gliricidia sepium,* SEM: Standard error of the mean

Table 3. There were no (p>0.05) differences in nitrogen intake on the sole *Moringa* diet and 50 MO:50 LEU but both were significantly (p<0.05) higher than the nitrogen intake on 50 MO:50 GLI. Non-significant (p>0.05) diet effects were also observed for faecal nitrogen losses. Significant (p<0.05) diet effects were however observed with urinary nitrogen losses with the highest value being obtained on the 50 MO:50 LEU diet and the least losses with the sole *Moringa* diet. Significant (p<0.05) diet effects were however observed with urinary nitrogen losses with the highest value being obtained on the 50 MO:50 LEU diet and the least losses with the sole *Moringa* diet. The same pattern was observed for the total nitrogen losses in absolute terms. Nitrogen retention was positive and high for all the three experimental diets. The highest nitrogen retention values, in absolute terms and as percentages of total nitrogen intake (6.02 g g^{-1}; 80.37%), were obtained with the sole *Moringa* diet.

DISCUSSION

The observed nutrient compositions for the experimental fodders fell within earlier reported ranges (Tian *et al.*, 1998; Odeyinka *et al.*, 2003; Asaolu and Odeyinka, 2006; Asaolu *et al.*, 2010). The crude protein concentrations were high compared to the mean value of tropical grass species which seldom exceed a level of 15.00 g/100 g (Reynolds *et al.*, 1992). They were also higher than the recommended range of 7.0-8.0 g/100 g DM for efficient functioning of rumen microorganisms (Van Soest, 1994). The CP concentrations also exceeded the range of 11.0-13.0 g/100 g DM known to be capable of supplying adequate protein for maintenance and moderate growth in goats (NRC, 1981; Poppi and McLennan, 1995). The ADF and NDF values of all the experimental fodders/fodder combinations were low to moderate when compared with low quality forages which ruminants effectively degrade (Arigbede and Tarawali, 1997; Okoli *et al.*, 2003). They also compare favourably with those reported (Oduguwa *et al.*, 1999; Oji and Isilebo, 2000; Okoli *et al.*, 2003) for selected browses of southern Nigeria. The organic matter concentrations for leucaena and gliricidia were comparable to those reported by Aregheore (2004) while the value obtained for *Moringa* was also comparable to that obtained by Asaolu *et al.* (2009b).

Generally, mineral elements are acknowledged to be important to proper nutrition. Many minerals, particularly Ca, P and Na, are essential for small ruminants for optimum productivity (Ghazanfar *et al.*, 2011). Mineral contents in feed resources, their strengths and weaknesses are important to know, especially for goats where browse, forbs and weeds which have not been studied analytically very much, play such a vital feeding role (Devendra, 1995). Norton (1994) reported that Ca is rarely limiting in forage diets although legumes and browses have been indicated to have more concentration of Ca than the grasses. Minson (1990) stated that it is unlikely for Mg to be critically low in tropical forages. Unlike the macro-minerals, the requirements of goats for most micro-minerals have not been well established. However, Zn requirement for goats is put at a minimum of 10 mg kg^{-1} diet dry matter (NRC, 1981) while Mn requirements may be around 20 mg kg^{-1} diet dry matter (Anke *et al.*, 1973; Gibbons *et al.*, 1976; NRC, 1981). All the fodders, singly and in combinations were observed to contain higher levels than these estimated minimum requirements (Table 1). Copper requirements need to consider present molybdenum levels and other interfering substances such as S, Zn, Fe and Ca, although goats have not been studied sufficiently enough for any estimates (Haenlein, 1987). An Fe requirement of 100 mg kg^{-1} DM intake has been stated for dairy cattle (NRC, 1978). Sheep of all classes are supposedly adequately provided with 30 mg kg^{-1} DM intake (NRC, 1985). However, it had been previously reported (Lintzel and Radeff, 1931) that iron requirements of newborn goat kids may be more critical than in cattle or sheep. In addition, internal parasite infestations are usually more serious in goats than in cattle and may require higher levels to prevent anaemia, more often observed in goats than in cattle (Haenlein, 1987). The amounts of Fe present in the experimental fodders could probably be sufficient to meet the needs of a growing goat. Haenlein (1987) reported that no immediate dangers of clinical deficiency diseases due to these micro-mineral content of forages is affected by soil mineral level, soil pH, environmental temperature and season of the year.

Feed intake has been described (Masafu, 2006) a measure of diet appreciation, selection and consumption by an animal. It is a key process which determines the quantity of feedstuff which is ingested over a period of time, usually per day (McDonald *et al.*, 1993). It is regarded as one of the major factors which determine potential animal performance other than feed digestibility (Beever, 1993). These obtained dry matter intake and digestibility results suggest equal potentials of acceptability, consumption and utilization of the experimental diets by WAD goats. Apparently higher values were however obtained in favour of the sole *Moringa* fodder. The observed non-significant (p>0.05) differences could be explained by the reports that voluntary dry matter intake and dry matter digestibility are dependent on the cell wall constituents (fibre), especially neutral detergent fibre and lignin (Bakshi and Wadhwa, 2004). Feedstuffs with low NDF (20-35%) are more digestible than those with more than 35% (Norton, 1994). The NDF values in this study ranged from 26.35% for the sole *Moringa* fodder to 27.98% for the 50 MO:50 GLI (Table 1). Relative Feed Value (RFV) is a widely accepted forage quality index in the marketing of hays in the United States of America. It was developed by the Hay Marketing Task Force of American Forage and Grassland Council (Rohweder *et al.*, 1978). RFV combines the estimates for forage digestibility and intake into a single number. All the three experimental diets (Table 2) have potentials for energy intake as they were all higher than the baseline figure of 100. Forages are ranked relative to the digestible dry matter intake of alfalfa, assuming 41% ADF and 53% NDF with RFV of 100. The author recommended that a lower RFV forage should be included with unusually high RFV hay to slow the rate of passage. The RFV reported by Kiraz (2011) for some legume hays harvested at flowering stage were high and ranged from 138.81 and 155.07 but were lower than the values obtained in this study. Variations in the RFV of forages are associated with NDF and NDF contents, extent of forage lignifications and leaf:stem ratios (Hides *et al.*, 1983; Wilson *et al.*, 1991; Canbolat *et al.*, 2006).

The nitrogen intake values obtained in this study were higher than those (3.04-3.19 g/animal/day) reported by Ajayi *et al.* (2005) for WAD goats fed some other forages as supplements to a basal diet of *P. maximum*. They were however comparable to the values reported by Asaolu *et al.* (2010) for WAD goats on *Moringa* and bamboo-supplemented groundnut hay diets. Alli-Balogun *et al.* (2003) reported slightly higher average nitrogen intake level of 9.2 g day^{-1} for Yankassa/WAD sheep crosses fed grass supplemented with cassava foliage or groundnut hay. Fadiyimu *et al.* (2010) also obtained an average of 9.28 g day^{-1} for WAD sheep fed various levels of *Moringa oleifera* as supplement to *Panicum maximum*. Such differences may be attributed to dry matter intake levels and nitrogen concentrations of the experimental feedstuffs. The observed non-significant (p>0.05) differences in faecal nitrogen losses agree with the findings of Black *et al.* (1978), Fadiyimu *et al.* (2010) and Asaolu *et al.* (2010) that faecal nitrogen was not affected by nitrogen intake. The observed trend in faecal nitrogen losses could be attributed to apparent protein digestibility which ranged from 83.88% for 50 MO:50 GLI to 89.35% and with no (p>0.05) significant differences (Table 2). As observed in this study, several earlier researchers Ajayi *et al.* (2005), Ahamafule *et al.* (2006), Fadiyimu *et al.* (2010), Asaolu *et al.* (2010) have also reported significant (p<0.05) diet effects on urinary nitrogen. The high nitrogen retention values obtained in this study (Table 3) probably indicate that the protein requirements for maintenance were adequately met by the diets (Fadiyimu *et al.*, 2010). Ajayi *et al.* (2005) opined that high nitrogen retention could be as a result of high crude protein content which ranged from around 24 to almost 28% (Table 1) for the experimental diets. The nitrogen retention values suggest that the sole *Moringa* diet had the highest efficiency of protein utilization. *Moringa oleifera* had been reported in an earlier study (Asaolu *et al.*, 2010) to improve the efficiency of protein utilization on a groundnut hay based diet.

CONCLUSION

Moringa oleifera, *Leucaena leucocephala* and *Gliricidia sepium* sufficient amounts of crude protein required by small ruminants. However, only *Moringa* contained sufficient amounts of P and Na that are required in the diet of goats. The intake, nutrient digestibility, nitrogen utilization and predicted relative feed values were high and comparable. Combinations of *Moringa* with either *Leucaena* or *Gliricidia* are recommended to allow for an optimal utilization of the available *Moringa* fodder its currently limited availability in Nigeria.

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