Nutrient Digestibility and Growth Performance of West African Dwarf (WAD) Goats Fed Foliage Combinations of Moringa oleifera and Gliricidia sepium with Equal Proportions of A Low-cost Concentrate

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Abstract
Forty growing WAD goats (20 males and 20 females) were used in a 20-week digestion and growth study (complete randomized design) to investigate the potentials of a formulated low-cost concentrate with gliricidia and/or moringa fodder combinations to alleviate the acknowledged dry season nutritional stress often associated with ruminants in tropical environments. Eight animals (4 males and 4 females) were allocated to each of five experimental diets, namely; concentrate with 100 % gliricidia and 100 % moringa respectively (LC:G100M0, LC:G0M100), concentrate with gliricidia and moringa combinations at 75 to 25 %, 50 to 50 % and 25 to 75 % respectively (LC:G75M25, LC:G50M50, LC:G25M75). Performance indicators were nutrient intake, nutrient digestibility coefficients, feed conversion ratios and growth rates. Total DM intake was significantly ($P<0.05$) higher at LC:G0M100 (85.80 $g/kg^{0.75}$) relative to LC:G100M0 (74.80 $g/kg^{0.75}$). Forage combinations resulted in significantly ($P<0.05$) greater total DM intakes, with LC:G50M50 (92.10 $g/kg^{0.75}$) having the most significant ($P<0.05$) effect. For virtually all the nutrient intakes, the least values resulted from LC:G100M0. Critical nutrient (CP, GE) intake values, a number of apparent nutrient digestibility coefficients (CP, TDN), growth performance indices (total weight gain and daily growth rate) and feed utilization efficiency were highest for animals on LC:G0M100. Notwithstanding the overall superiority of LC:G0M100 however, LC:G50M50 would be recommended to resource-limited small ruminant farmers in order to optimize the use of available feed resources. This is in view of non-significant ($P>0.05$) differences of these two diet combinations in CP intakes (73.90 vs. 71.10 g/d), apparent CP digestibility coefficients (86.00 vs. 84.90 %), TDN values (83.70 vs. 79.50 %), total weight gains (7.18 vs. 6.44 kg) and daily growth rates (51.30 vs. 46.00 g/d).
Keywords: Digestibility, dry season nutritional stress, *Gliricidia sepium,* growth performance, low-cost concentrate, *Moringa oleifera,* WAD goats

Introduction

Principal among the natural diets of ruminants are the natural pastures, and they abound in the tropics. In Nigeria, goats contribute about 24 % of the meat supply; thus making them the second most important livestock species in the country (Oni, 2002). As observed by Okoruwa *et al*. (2013) however, goats in Nigeria suffer severe nutritional stresses in the dry season as a result of the acknowledged seasonal fluctuations in availability and quality of natural pastures, as characterized by their low production, reproductive performance, slow growth rate and increased susceptibility to pests and diseases (Tolera *et al*., 2000). Scientists have advocated the feeding of supplements such as concentrates as part of the ways to improve the productivity of these animals during the dry season (Aregheore *et al*., 2004). Concentrate usually means high quality, low fibre feeds including cereals and milling by-products (Van, 2006). Concentrate feeds promote rapid growth of ruminants, reduce ruminal methane production and increase propionate production, thereby lowering energy losses and contributing to higher efficiency of nutrient utilization (McDonald *et al*., 1996), and their use as supplements in intensive production systems has been the subject of several excellent reviews including that of Bangani *et al*. (2000), although they are often not fed due to their unavailability and high cost (Nouala *et al*., 2006). Fortunately for the ruminant stock however, their concentrate feed requirements are relatively small and can comprise of higher proportions of “other concentrate ingredients” that can minimize cost (FAO, 1995). Sultana *et al*. (2015) opined that utilization of fodder trees and shrubs could be a potential strategy for increasing the quality and availability of feeds for resource-limited ruminant livestock farmers during the dry season. The trees are reported (Moyo *et al*., 2012) to provide a good and cheaper source of readily fermentable energy, nitrogen and micronutrients. Generally, they establish easily and require few agronomic inputs (Mengistu, 1997). According to Okoli *et al*. (2003), these multipurpose trees could be considered as a more reliable feed resource of high quality to develop sustainable feeding systems and in increasing livestock productivity. More attention is now being given to trees and shrubs for feeding sheep and goats in most areas of the world with promising results (Ayuk *et al*., 2007).

Gliricidia sepium is an extremely versatile plant which fulfills a number of roles in smallholder agricultural production systems (Fasae *et al*., 2010). The forage has been identified as one of the fodder legumes that promote rumen ammonia production and liveweight gain of animals (Ajayi *et al*., 2005). Due to the high feeding value, gliricidia forage has been used extensively to feed small ruminants with satisfactory results (Flavey, 1982; Odeyinka, 2001; Asaolu and Odeyinka, 2006). *Moringa oleifera* is a remarkable species with its high nutritional value and good biomass production which can be used as a nutritional supplement (Sanchez *et al*., 2006). It is a non-leguminous multipurpose tree and is one of the fastest growing trees in the world, with leaves high in good quality, highly digestible protein and contains negligible amounts of anti-nutritive compounds (Asaolu *et al*., 2009; Ogbe and Affiku, 2011; Makkar, 2012; Aye and Adegun, 2013). The leaves of *Moringa oleifera*, as fresh fodder (Asaolu *et al*., 2010; Adegun *et al*., 2011), and as moringa leaf meal and feed components in animal production, especially goats, (Asaolu *et al*., 2011; 2012; Moyo *et al*., 2012) are gradually gaining importance in the West African sub-region to address the observed crude protein shortages of natural pastures and crop residues (Sultana *et al*., 2015). Concentrate feeds have varying roles in feeding systems for ruminant animals, depending on the roughage or forage resources available and the required levels of productivity (Preston and Leng, 1987). Possible synergies between foliage combinations of moringa and other multipurpose trees with formulated concentrates, especially low-cost ones, on nutrient intake and utilization as well as growth of indigenous Nigerian small ruminants are, however, yet to be exploited for improved productivity.

This study was therefore designed to assess the nutrient utilization and growth performance of West African Dwarf (WAD) goats fed *Moringa oleifera* and *Gliricidia sepium* foliages, singly and in three different combinations alongside a formulated low-cost concentrate.

Methodology

Experimental site

The study was conducted over a period of twenty weeks at the Goat Unit of the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria, located within the tropical savanna climate zone. Ile Ife has an average annual rainfall of 1000 to 1250 mm, usually from March to October, and a mean relative humidity of 75 to 100 % (Ife - Wikipedia, the free encyclopedia). Although a highly commercialized city, Ile Ife is surrounded by rural settlements where agriculture is the chief occupation. It is located between latitudes 7°28'N and 7°45'N and longitudes 4°30'E and 4°34'E (Ajala and Olayiwola, 2013).

Procurement of experimental forages, and feed ingredients for concentrate formulation

Fresh *Moringa oleifera* and *Gliricidia sepium* forages were harvested daily from established plots at the Teaching and Research Farm, Obafemi Awolowo University, Ile Ife. Feed ingredients that were used in formulating the experimental concentrate were sourced from a reputable feed ingredient store in Ile Ife.

Formulation of experimental concentrate

An experimental concentrate was formulated from palm kernel cake, wheat offal, maize, groundnut cake, bone meal and salt using the proportions indicated in Table 1.

Table 1: Composition of a formulated low-cost concentrate for experimental WAD goats

Ingredients	Levels (%)
Palm kernel cake	60.00
Wheat offal	20.00
Maize	9.75
Groundnut cake	8.00
Bone meal	2.00
Salt	0.25
TOTAL	**100**

Experimental diets

There were five (5) experimental diets that comprised of *Gliricidia sepium* and *Moringa oleifera* fodders, singly and in combinations, along with the formulated low-cost feed concentrate (Table 1), offered at 4 % of body weight of the animals (dry matter basis). The fodder components of the experimental diets were:

100 % *Gliricidia sepium* (G100M0)
75 % *Gliricidia sepium* + 25 % *Moringa oleifera* (G75M25)
50 % *Gliricidia sepium* + 50 % *Moringa oleifera* (G50M50)
25 % *Gliricidia sepium* + 75 % *Moringa oleifera* (G25M75)
100 % Moringa oleifera (G0M100)

For each experimental diet, the fodder component was offered at 2 % of body weight (DM basis) and the concentrate was also offered at 2 % of body weight (DM basis). The *Gliricidia sepium* and *Moringa oleifera* fodder combinations were thoroughly mixed to eliminate/minimize animal selection.

Experimental animals and management

Forty (40) WAD growing goats (20 males and 20 females), 5 to 7 months old and weighing between 4.2 and 8.2 kg, were purchased from reliable small ruminant markets within Ile Ife and environs. The animals were thereafter quarantined for a period of three weeks. During this period, they were administered with oxycare antibiotic injection for three days at the rate of 1ml per 10kg body weight through intramuscular route for prophylactic treatment. Subcutaneous administration of Ivermectin injection was carried out for each animal at the rate of 0.2 ml/10 kg body weight against internal and external parasites. The animals were offered roughly equal proportions of *Moringa oleifera* and *Gliricidia sepium* forages on an *ad libitum* basis, with concentrate supplementation at 150 g/head/day throughout the quarantine period.

Following the quarantine period, the animals were randomly allotted to five (5) experimental treatments at eight (8) animals per treatment in a complete randomized design for a 20-week combined growth and digestion experiment, with a balance maintained for weight and sex. They were thereafter moved into pens that measured 4.32 m^2 (3.6 X 1.2 m) each, in groups of 4 animals of the same sex /pen for the growth phase, while the animals were housed individually in metabolic cages, designed for a complete separation of faeces and urine, during the two digestion trials that were conducted from the 9^{th} to 10^{th}, and 15^{th} to 16^{th} weeks respectively. The first week of each digestion trial served as the acclimatization period to the metabolic cages while the second week served as the faecal and urinary collection period. All pens and cages were equipped with feeding and watering facilities. The 20-week experiment was preceded by a 14-day adaptation period. The animals were weighed individually at the commencement of the experiment, and subsequently weekly before feeding throughout the experimental period. The animals were offered their respective experimental feeds between 08.00 and 09.00 hours with the concentrate and fodder/fodder combination being offered simultaneously in separate feeding troughs. Fresh clean water was also supplied ad lib daily. Feed refusals were measured daily before feeding in order to estimate the previous day's feed intake by each animal.

During the two digestion trials, faecal outputs were measured. Ten percent of daily faecal output by each animal was taken, dried in a forced-draught oven at 70^o C for 72 hours to determine the dry matter content and stored at 4^o C During the faecal collection periods, 150-gm samples of *Gliricidia sepium* and *Moringa oleifera* were taken daily and dried in a forced-draught oven at 70^o C for 72 hours to determine the dry matter content and stored at ambient temperature for later analysis for chemical constituents.

Chemical analysis

At the end of the trials, the daily stored faecal samples were bulked, thoroughly mixed, re-dried in a forced-draught oven at 70^o C for 72 hours, ground and sub-sampled for chemical analysis. The stored *Gliricidia sepium* and *Moringa oleifera* samples were also re-dried in a forced-draught oven at 70^o C for 48 hours and sub-sampled for chemical analysis. The faecal and fodder samples were then separately and individually milled to pass through a 2-mm mesh. A sample of the experimental concentrate was similarly milled to pass through a 2-mm mesh, and sub-sampled for dry matter determination in a forced draught oven at 70^o C for 48 hours. The feed (fodder and concentrate) and faecal samples were analyzed for crude protein, crude fibre, ether extracts, ash and nitrogen-free extracts as described by AOAC (1990). Gross energy values of the feed samples were determined using a ballistic bomb calorimeter.

Statistical analysis

Data obtained were analyzed with the Analysis of Variance using General Linear Model of SAS (2008). Significant means were separated using the Duncan's New Multiple Range Test of the same package at 5 % level of significance.

Results and Discussion

Chemical compositions of the experimental feeds fed to growing West African Dwarf goats

The chemical compositions of the experimental fodders and concentrate are shown in Table 2. The formulated concentrate was high in dry matter content while the forages had relatively lower dry matter contents. The three feeds appeared comparable in organic matter and ash contents. Crude fibre levels were also comparable for the three feedstuffs (lower than 18 %), although with the level in *Gliricidia sepium* being the highest (16.37 %). Crude protein level was higher than 20 % for all the three feeds, but it was highest in *Moringa oleifera* followed by *Gliricidia sepium* and the concentrate respectively. Ether extract was highest for *Moringa oleifera* followed by the level in the concentrate while the level in *Gliricidia sepium* was comparatively very low. Levels of nitrogen free extracts were almost the same in *Gliricidia sepium* and the concentrate, while both were relatively higher than the value that was obtained for *Moringa oleifera*. The concentrate had the highest gross energy value, followed by *Moringa oleifera* and *Gliricidia sepium* respectively. *Moringa oleifera* had almost twice the gross energy content of *Gliricidia sepium* (4.48 vs. 2.64 MJ/kg).

The ingredient composition of the experimental concentrate as contained in Table 1 shows that it contained much less of maize and groundnut cake than a typical concentrate. According to FAO (1983) and Van (2006), concentrate usually means high quality, low fibre feeds (less than 18 %) including cereals and milling by-products; with cereals constituting the major proportion of typical concentrate feeds, amounting to over 60% of the total including roots and tubers (FAO, 1995). The total proportion of maize and groundnut cake ("conventional" concentrate feedstuffs) was however less than 20 % of the experimental concentrate. This would go to some extent in further alleviating the acknowledged competition (Fasae e*t al*., 2010) between man and his animals for edible grains, as well as minimize the use of feed ingredients that are often not fed due to their unavailability and high costs (Nouala *et al*., 2006). Generally, ruminant concentrate feeds can include higher proportions of "other concentrates" (FAO, 1995) such as palm kernel cake and wheat offals that were the principal components (80 %) of the experimental concentrate. Moreover, goats are considered superior to other ruminant species in their utilization of poor quality and high fibre feedstuffs (Oyeyemi and Akusu, 2005) such as palm kernel cake and wheat offals. Relative to *Gliricidia sepium* and *Moringa oleifera*, the concentrate could be a poorer source of minerals because of its relatively lower ash content (Table 2). However, it compares favourably with the two fodders in crude protein level required by ruminants for optimum microbial gut activities (ARC, 1980; NRC, 1985), and just like the experimental fodders, exceeded the crude protein range of 11.00 to 13.00% that is known to be capable of supplying adequate protein for maintenance and moderate growth in goats (NRC, 1981). The two experimental fodders also contained more than 20 % CP; in line with the observation of Waldroup and Smith (2008) that multipurpose trees contain 20 % and above in their leaves. The CP value of 26.65 % obtained for *Gliricidia sepium* in this study was slightly higher than the range of 14.70 to 21.64 % in some earlier (Devendra, 1992; Asaolu *et al*., 2012) reports. According to Brisibe *et al*. (2009), such variations could be due to genetic background, environment, cultivation methods as well as variations due to sample preparation methods and analysis. The CF values of the experimental moringa and gliricidia leaves were within the range (<18.00 %) expected of all forages fed fresh (Animal Nutrition Sub-Committee on Feed Composition; cited by Ash and Norton, 1987). The concentrate could have a moderating effect on fibre intake when fed alongside *Gliricidia sepium* fodder; although ruminant feed CF values similar to the values observed in this study have been reported by various authors such as Sowande (2004) and Idowu *et al*. (2013). Such levels were described as being important in the maintenance of optimal ruminal activities. Gu (2002) reported that CF functions in maintaining micro-ecological balances of the gut, promoting digestive system development and raising reproductive performance. The gross energy value of 14.07 MJ/kg for the experimental concentrate, though lower, appeared close to the reported value of 19.92 MJ/kg for maize (Heuzé and Tran, 2016). It was however much higher than the gross energy values of moringa and gliricidia fodders. Maize is the most common grain used for livestock feeding (Maner, 1987) and a standard component of livestock diets, especially swine and poultry, where it is used as a source of energy (Maner, 1987; Heuzé and Tran, 2016). Other grains are typically compared to maize when their nutritional value is estimated (Heuzé and Tran, 2016). With the relatively high crude protein (> 20.00 %), relatively low crude fibre (< 18.00 %), and high energy level of the experimental concentrate, it could possibly serve the dual purpose of protein and energy supplementation in ruminant nutrition. The higher gross energy content of *Moringa oleifera* relative to *Gliricidia sepium*, alongside other nutritional attributes, could be taken as an indication of its potential value as a sole feed for ruminant feeding.

Table 2: Nutrient composition of experimental feedstuffs fed to growing WAD goats

Parameters	Feedstuffs		
	Experimental Concentrate	*Gliricidia sepium*	*Moringa oleifera*
Dry matter (% ± SD)	91.48±0.49	23.68±3.65	28.11±2.08
% of DM (± SD)			
Organic matter	94.53±0.28	92.14±1.46	91.69±3.29
Crude protein	20.67±0.28	26.65±1.53	29.14±1.49
Crude fibre	10.48±1.07	16.37±2.00	10.34±1.00
Ether extracts	18.41±1.19	4.57±1.09	28.40±1.95
Ash	5.47±0.28	7.86±1.46	8.27±1.25
Nitrogen free extracts	45.06±1.59	44.53±5.37	23.80±6.82
Gross Energy (MJ/kg ± SD)	14.07±0.41	2.64±0.02	4.48±0.04

Intake and digestibility of the experimental feeds fed to growing West African Dwarf goats

The nutrient intake and apparent digestibility data obtained for the animals on the experimental diets are shown in Table 3. Concentrate dry matter intake was observed to be significantly (P<0.05) highest at forage combination of 75 % gliricidia and 25 % moringa. Total DM intake, in absolute terms, was comparable (P>0.05) for LC:G75M25, LC:G50M50, LC:G25M75 and LC:G0M100, with their values all being significantly (P<0.05) higher than the value for LC:G100M0. When the forages were respectively offered singly in combination with the concentrate, WAD goats tended to eat more of the concentrate as a proportion of the diet combination with gliricidia relative to moringa (62.35 Vs. 53.99 %). However, when the two forages were combined, total DM intake increased with increasing moringa inclusion levels in the forage combinations; with an optimum value obtained at 50 % inclusion levels each of both moringa and gliricidia in the forage combination. When the DM intakes were expressed relative to metabolic body weight, the significant effects of the various dietary treatments on total DM intake were better highlighted. Based on this criterion, total DM intake was significantly (P<0.05) higher at concentrate supplementation of 100 % moringa forage relative to concentrate supplementation of 100 % gliricidia forage. In addition, forage combinations resulted in significantly (P<0.05) higher total DM intakes, with 50 % inclusion level each of both moringa and gliricidia in the forage combination having the most significant (P<0.05) effect. As for the other nutrients, intakes of CP, EE, ash and GE were also observed to be significantly (P<0.05) highest for animals on concentrate supplementation of 100 % moringa forage. The observed intake values could be taken as a reflection of the preference of the animals for *Moringa oleifera* over *Gliricidia sepium*; with the animals opting for more of concentrate with less available *Moringa oleifera* in the diet combinations. *Gliricidia sepium*, though introduced much earlier in southwestern Nigeria to combat the problem of the decline in yield and nutritive value of grasses (Odeyinka, 2000), has been reported to have, amongst others; limitations in palatability and presence of toxic substances (Attah-Krah and Reynolds, 1989; Akinbamijo *et al*., 2006). Lowry (1990) reported that animals refused gliricidia leaves even without tasting it. Shelton (2000) also reported palatability problems encountered by small ruminants when fed with *Gliricidia sepium*. On the other hand, *Moringa oleifera* was reported (Makkar and Becker, 1996) to possess negligible amounts of anti-nutritive compounds. Fadiyimu *et al*. (2011) also reported *Moringa oleifera* to be the most preferred by West African Dwarf sheep among eight selected browse plants, *Gliricidia sepium* inclusive, irrespective of the newness of introduction of *Moringa oleifera* to the animals. This result was seen as a reflection of the higher relative palatability of moringa, better nutrient profile and lower anti-nutritional factors content, particularly phytate; with gliricidia containing almost three times the level of phytate in moringa (7.21 Vs. 2.60 %). The significantly (P<0.05) highest DM intake (when expressed relative to metabolic body weight) at 50 % level of each fodder in the fodder combination is in line with the reports of other authors (Bosman *et al*., 1995; Aregheore *et al*., 1998) who asserted that there were better production outcomes in browse mixtures than in single browses. Adegun (2014) opined that such results could result from improved palatability due to the combination of the two fodders.

While dry matter was digested to the same (P>0.05) extent across all the experimental treatments, significant (P<0.05) differences were observed in the digestibility of all the other nutrients (Table 3). Four of the nutrients (DM, CP, EE and NFE) were highly digested while CF and ash were poorly digested. It was also observed that the diet combination of the formulated concentrate and sole moringa forage (LC:G0M100) had the highest value for every nutrient digestibility, except for CF digestibility. Crude fibre digestibility was least (P<0.05) when either of the two forages was fed singly along with the formulated concentrate, while it was significantly (P<0.05) highest at forage combinations of 25 and 75 % either way, with the formulated concentrate. Crude protein digestibility was comparable (P>0.05) for LC:G0M100 and diets containing formulated concentrate with the various fodder combinations, with the diet containing formulated concentrate and sole gliricidia forage being the only diet combination with a significantly (P<0.05) lower crude protein digestibility. Ether extract and ash digestibility values followed virtually the same trend across all the experimental treatments, with the diet combination of the formulated concentrate and sole gliricidia forage (LC:G100M0) having the least value (P<0.05) for both parameters. Moringa inclusion at 25 and 50 % levels in the forage combinations improved (P<0.05) nitrogen free extract digestibility relative to the sole gliricidia forage, but this advantage was reversed (P<0.05) at 75 % inclusion level. The diet combination of formulated concentrate and sole moringa forage (LC:G0M100) had the highest (P<0.05) total digestible nutrients, while LC:G100M0 had the least value. The high apparent digestibility values obtained for four (DM, CP, EE and NFE) of the six major nutrients showed that the experimental diets were relatively well degraded in the rumen. Increasing CP digestibility with increasing levels of moringa in the forage combinations could be attributed to the higher content of by-pass protein in moringa relative to gliricidia leaves (47 Vs. 30 %; Becker, 1995). The dietary CF digestibility values could be a reflection of the CF contents of the forage components of the diets. Ukanwoko and Ibeawuchi (2009) reported that higher dietary CF digestibility coefficients with higher CF contents of dietary components. A similar observation was attributed by Okoruwa and Bamigboye (2015) to ingredient matrix of diets, levels of fibre and individual variations among the animals fed the experimental diets. Increasing EE values with increasing moringa levels in the forage combinations shows that EE digestibility increased with increasing EE levels in the dietary combinations. This confirms the reports of Okoruwa *et al*. (2013) and Okoruwa and Bamigboye (2015) that ether extract content of a diet is essential for the assessment of its digestibility. In line with the reasoning of Okoruwa and Bamigboye (2015), the generally low ash digestibility values observed in this study could be attributed to the interactions among ingredient components of the experimental diets which adversely affected microbial activity in the rumen. It could also be seen (Table 1) that the two forages and experimental concentrate that were used in this study were relatively low in total ash. Hansen *et al*. (2007) had reported that information on the ash content of a diet is essential for the assessment of its digestibility. Studies on TDN have been shown (Aye and Adegun, 2010; Okoruwa *et al*., 2013) to be important in the estimation of nutrients that are really available for animal performance. The TDN figures obtained in this study could be taken as an indication that moringa forage provided more nutrients that were really available for the performance of the experimental animals; with TDN values having a direct relationship with moringa levels in the forage combinations. Hence, the highest TDN value of 83.70 % observed for FC:G0M100 could, as opined by Okoruwa and Bamigboye (2015), be an indication of better proportion of energy and protein sources in the diet that were appropriate for the enhancement of growth performance in goats on the diet.

Table 3: Intake and nutrient digestibility of diet combinations of a low-cost concentrate with *Gliricidia sepium* and/or *Moringa oleifera* fed to West African Dwarf goats

Parameter	Diet combination					SEM
	LC: G100M0	LC: G75M25	LC: G50M50	LC: G25M75	LC: G0M100	
Number of animals	8	8	8	8	8	-
Days in experiment	140	140	140	140	140	-
Feed intake, gDM/d						
LC	157.30^{c} (62.35 %)	165.60^{a} (56.93 %)	160.10^{bc} (54.17 %)	156.50^{c} (54.55 %)	162.40^{ab} (53.99 %)	1.16
G	95.00^{a} (37.65 %)	86.90^{a} (29.87 %)	58.40^{b} (19.76 %)	35.80^{c} (12.49 %)	-	8.95
M	-	38.40^{c} (13.20 %)	77.00^{b} (26.06 %)	94.60^{b} (32.97 %)	138.30^{a} (46.05 %)	13.83
Total DMI, g/d	252.30^{b}	290.90^{a}	295.50^{a}	286.90^{a}	300.80^{a}	6.20
Total DMI (g/kg$^{0.75}$)	74.80^{c}	90.00^{ab}	92.10^{a}	89.20^{ab}	85.80^{b}	2.12
Nutrient intake, g/d						
CP	57.80^{b}	68.60^{a}	71.10^{a}	69.40^{a}	73.90^{a}	1.95
CF	32.00^{b}	35.60^{a}	34.10^{ab}	32.10^{b}	31.30^{b}	0.60
EE	33.30^{d}	45.40^{c}	54.00^{b}	57.30^{b}	69.02^{a}	4.06
Ash	16.10^{b}	19.00^{a}	19.70^{a}	19.10^{a}	20.30^{a}	0.53
NFE	113.20^{bc}	122.40^{a}	116.50^{ab}	109.00^{bc}	106.10^{c}	2.02
GE intake, Mcal/g	5.80^{c}	6.50^{b}	6.60^{b}	6.50^{b}	6.90^{a}	0.12
Apparent digestibility coefficients, %						
DM	60.60	64.30	64.60	62.40	66.40	0.79
CP	81.40^{b}	84.40^{a}	84.90^{a}	84.20^{a}	86.00^{a}	0.39
CF	26.50^{b}	36.30^{a}	30.20^{ab}	36.00^{a}	29.50^{b}	1.44
EE	63.70^{c}	72.30^{b}	72.60^{b}	73.10^{b}	78.80^{a}	0.98
Ash	21.60^{c}	27.50^{b}	30.70^{ab}	27.50^{b}	33.60^{a}	1.49
NFE	63.70^{bc}	65.10^{ab}	64.50^{ab}	59.30^{c}	69.20^{a}	0.84
TDN	68.10^{c}	75.50^{b}	79.50^{ab}	77.70^{b}	83.70^{a}	1.11

. [a,b,c,d]Means within each row with different superscripts are significantly different at P<0.05.

LC = Low-cost concentrate, G = *Gliricidia sepium*, M = *Moringa oleifera*, DM = Dry matter, CP = Crude protein, CF = Crude fibre, EE = Ether extract, NFE = Nitrogen free extract, GE = Gross energy, TDN = Total digestible nutrients

Growth performance of West African Dwarf goats fed a low-cost concentrate with forage combinations of Gliricidia sepium and Moringa oleifera

Table 4 shows that there were significant (P<0.05) dietary treatment effects on the growth performance indices of the experimental animals. All the experimental diets resulted in positive weight changes, but higher changes were observed with increasing moringa inclusion levels in the diets. Weight gains were comparable (P>0.05) for animals on LC:G0M100 and LC:G25M75; and a similar observation was also made for animals on LC:G50M50 and LC:G75M25. The least (P<0.05) weight gain was observed for animals on the diet combination of formulated concentrate and sole gliricidia fodder. The mean feed conversion ratios showed that significantly (P<0.05) increasing amounts of the experimental diets were consumed by the animals per unit weight gain with decreasing proportions of moringa fodder in the diet combinations, with the highest (P<0.05) ratio being observed for animals on concentrate supplementation of sole gliricidia fodder.

The growth rates obtained in this study were much higher than the reported (Okolo et al., 2012) range of 10.60 to 24.60 g/d for WAD goats that were fed graded levels of cashew nut shell with some other less conventional feed concentrates. They were also higher than the range of 14.88 to 21.43 g/d reported by Asaolu et al. (2012) for WAD goats that were offered dried leaves of moringa, gliricidia and leucaena as supplements to a basal diet of cassava peels. The growth rates of the animals on forage combinations with high moringa proportions (> 50 %) were however comparable to the reported values (46 to 56 g/d; Babayemi et al., 2006) for WAD goats fed Panicum maximum-based diets supplemented with lablab, leucaena and gliricidia foliages. The growth performance of the experimental animals could be seen to reflect their nutrient utilization as depicted by the apparent nutrient digestibility coefficients and TDN values as contained in Table 3. Similar trends had earlier been reported by Okoruwa *et al*. (2013) and Okoruwa and Bamigboye (2015), with an assertion that an efficient utilization of nutrients that supply adequate energy and protein is required for optimum growth performance in livestock (Okoruwa *et al*., 2013). The observed trend of feed to gain decreasing linearly with increasing protein intake was also reported by Adegun and Aye (2013) in a study with West African Dwarf rams offered *Moringa oleifera* and cotton seed cake as protein supplements to *Panicum maximum*. Tyler *et al*. (1983) had earlier made the same observation with growing boars offered varying levels of crude protein.

Table 4: Mean growth performance indices of West African Dwarf goats fed a low-cost concentrate with forage combinations of *Gliricidia sepium* and *Moringa oleifera*

Parameter	Experimental diets					SEM
	LC: G100M0	LC: G75M25	LC: G50M50	LC: G25M75	LC: G0M100	
No of animals	8	8	8	8	8	-
Days in expt.	140	140	140	140	140	-
Initial wt. (Kg)	6.25	6.26	6.26	6.25	6.25	0.44
Final wt. (Kg)	11.26^{b}	11.90^{ab}	12.70^{ab}	13.29^{a}	13.43^{a}	0.56
TWG (Kg)	5.01^{b}	5.64^{ab}	6.44^{ab}	7.04^{a}	7.18^{a}	14.00
GR (gd^{-1})	35.80^{b}	40.20^{ab}	46.00^{ab}	50.30^{a}	51.30^{a}	0.12
FCR	7.10^{a}	7.30^{a}	6.40^{b}	5.70^{c}	5.80^{c}	0.25

^{a,b,c,d}Means within each row with different superscripts are significantly different at P<0.05.
LC = Low-cost concentrate, G = *Gliricidia sepium*, M = *Moringa oleifera*, TWG = Total weight gain, GR = Growth rate, FCR = Feed conversion ratio

Conclusions and recommendation

Highest dry matter intake by growing West African Dwarf goats resulted from the diet combination of the low-cost concentrate with a forage combination of equal mixture of *Gliricidia sepium* and *Moringa oleifera*. For virtually all the nutrient intakes, the least values resulted from diet combination of the low-cost concentrate and sole *Gliricidia sepium* forage. Critical nutrient (crude protein, gross energy) intake values, growth performance indices (total weight gain and daily growth rate) and feed utilization efficiency were highest for animals on the experimental concentrate with sole *Moringa oleifera* forage. Notwithstanding the overall superiority of the diet combination of the low-cost concentrate with sole *Moringa oleifera* forage however, the diet combination of the low-cost concentrate with a forage combination of equal mixture of *Gliricidia sepium* and *Moringa oleifera* could be recommended to resource-limited small ruminant farmers in order optimize the use of available feed resources. This is in view of reasonable comparisons of these two diet combinations in crude protein intake, apparent crude protein digestibility coefficients, total digestible nutrients, total weight gain and daily growth rates.

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