

A nutritional and economic evaluation of *Moringa oleifera* leaf meal as a dietary supplement in West African Dwarf goats

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Abstract

Moringa oleifera leaves may have the potential to enhance nutritional status, growth performance, and health of ruminant animals when used as part of their diets. However, the nutritional value of the leaves for goats is largely unknown and needs to be investigated. Consequently, eighteen West African Dwarf (WAD) bucks weighing 7.0 ± 0.33 kg were used in a completely randomized design to evaluate the effects of diluting a conventional supplement with three levels of *M. oleifera* leaf meal (MOLM) on growth performance, haematology, and blood biochemical constituents. The MOLM was included in the commercial supplement at a rate of 0, 50, and 100 g/kg dry matter (DM). Including MOLM in the supplement did not significantly affect weight gain, dry matter intake, and metabolic weight gain of bucks. Packed cell volume (PCV), red blood cell (RBC), haemoglobin concentration (hb), and total protein were not significantly influenced by MOLM inclusion, either. However, blood urea concentration was significantly increased in bucks that were offered MOLM-based diets. All blood parameters, as well as alanine transaminase (ALT) and urea, were within the normal reference ranges for clinically healthy goats. The MOLM-based supplements had significantly lower feed cost per kilogram of weight gain and higher profit per kilogram of gain. It was concluded that diluting the commercial supplement with MOLM up to 100 g/kg DM does not impair the nutritional status, growth performance and health status of the goats while reducing the feed cost per gain.

Keywords: Cost, feed, growth, health, nutrition

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Introduction

As sources of animal protein and a measure against food insecurity, goats play a vital role in the economy of rural households in developing countries. They provide meat, milk, and skins, as well as income (Daramola *et al.*, 2005). In most developing countries, goat meat is in high demand because it is more affordable and leaner than the meat of other animals (Celik *et al.*, 2003). However, the productivity of goats is generally low owing to suboptimal rearing systems, in which goats are affected negatively by fluctuations in the quantity and quality of feed. The preference for low-input systems stems from the high cost of bought-in feeds. Indeed, the cost of some conventional feed ingredients, such as soybean and maize grain, is high owing to direct competition between humans and animals (Odunsi *et al.*, 2003). To improve the productivity of goats and hence their contribution to food and nutrition security, it is necessary to supplement them during the critical periods of feed inadequacy.

Because of the location of Nigeria in the tropics, where multipurpose tree species are ubiquitous, this problem can be curbed by supplementation with tree leaves. *Moringa oleifera* trees are capable of producing leaves throughout the year, and can therefore be used as nutritional supplements to low-quality grasses during the dry period (Roothaert & Paterson, 1997). *Moringa oleifera* is a slender deciduous perennial evergreen tree that originated in India, but has spread to other regions. It is one of the fastest growing trees in the world with high biomass yield, high crude protein of 31%, and an equitable level of other nutrients in

the leaves (Moyo *et al.*, 2011; Gopalakrishnan *et al.*, 2016). *Moringa oleifera* provides food, medicine, fuel, and other uses, but its potential as an important browse plant for small ruminants has not been fully evaluated. As well as the high level of protein, *M. oleifera* leaves contain considerable levels of carbohydrate, fat, vitamins, minerals, useful electrolytes and amino acids (Moyo *et al.*, 2011). The crude protein content compares favourably with other useful plant forage such as *Leucaena* and *Gliricidia* leaves (Owusu *et al.*, 2008). It has the potential to be used as a complete or partial replacement for common conventional feed sources.

Blood parameters are important in assessing the suitability and quality of feed ingredients in farm animals (Maxwell *et al.*, 1990), as they provide a good understanding of the nutritional and antinutritional effects of diets. Blood parameters provide vital information about the haematological profile of animals, which reflects their health status. Blood analysis is the fastest means of ascertaining toxicity of ingested feed in animals (Olafadehan, 2011). Tree leaves could be used as sources of nutrients for goats, but they contain secondary metabolites, the effects of which on nutrition and health are not always known. This study, therefore, was designed to investigate the effect of including MOLM as part of a supplement on growth performance and health status of WAD goats that were offered a *Panicum maximum* basal diet. It was hypothesized that replacing part of a commercial dietary supplement with MOLM, at the minimum, would have no negative effects on growth performance and health status of WAD goats. The overall objective of this study was to reduce the cost of supplementing goat diets through the use of ubiquitous *M. oleifera* leaves.

Materials and Methods

The experiment was conducted at the goat unit, Directorate of University Farms (DUFARMS), Federal University of Agriculture, Abeokuta, Ogun State, Nigeria. The farm is located in the humid tropical zone of south-western Nigeria with minimum and maximum temperatures of 20.66 °C and 35.48 °C, respectively. It is located at latitude 7°13'49.46"N and longitude 3°26'11.98"E. The altitude is 76 metres above sea level. Eighteen growing WAD bucks with average weight of 7.0 ± 0.33 kg were used in a 48-day feeding trial. The goats were quarantined and acclimatized for four weeks, during which they received oxytetracycline L.A. and a multivitamin mixture. In this period, the animals were introduced to the experimental diets in order to adapt their rumen microbes. The feeding trial commenced after acclimatization. The pens were cleaned every morning, and clean water was provided in the morning and evening. All animal husbandry practices were observed carefully to ensure proper hygiene. All procedures used in this experiment were in accordance with ethical standards of Animal Welfare Committee, College of Animal Science, Federal University of Agriculture, Abeokuta. The experiment proceeded after approval of the proposal by the Animal Welfare Group (Ethical clearance number COLANIM/APH/PG/12/0076.)

Fresh *Moringa* leaves were air-dried to constant weight at room temperature while retaining their greenish colouration. The leaves were then milled to pass through a 2-mm sieve. The resultant MOLM was stored at room temperature in jute bags until needed for inclusion in the commercial supplement. Three experimental supplements were formulated by replacing a conventional supplement (palm kernel cake (PKC), wheat offal, rice bran, oat meal, sheep premix and salt) with MOLM at a rate of 0, 50, and 100 g/kg (Table 1). The goats were fed on a basal diet of *P. maximum* in the morning (09:00), while the experimental supplements were offered in the evening (15:00). The basal diet was offered *ad libitum* to individual animals and the supplement was served at 4% bodyweight. The eighteen WAD goats were randomly divided into three treatment groups of six animals. Each group was randomly allotted to one of the three experimental supplements in a completely randomized design. The proximate compositions of MOLM and the experimental diets were carried out according to the methods of AOAC (2000). Moisture, ash, fat, and crude protein were determined according to AOAC method numbers 930.05, 930.05, 930.10, and 778.04, respectively. The fibre fractions were analysed according to the method of Van Soest *et al.* (1991).

Individual animals were weighed at the commencement of the experiment and at seven-day intervals throughout the 48-day experimental period. Weighing was done in the morning before feeding. The feed offered (concentrate diets) and refusals were weighed manually each day, thus feed intake was calculated as the difference between feed offered and feed refused. Bodyweights were used to calculate the daily weight gain and feed conversion ratio (FCR). The metabolic weight is expressed as the weight gain in gram to the exponential of 0.75. FCR was obtained using the formula:

$$\text{FCR} = \text{Feed intake (kg)} / \text{weight gain (kg)}$$

$$\text{Metabolic weight gain (g)} = \text{weight gain (g)}^{0.75}$$

Ten millilitres of blood were collected via jugular venepuncture from each animal using a hypodermic needle and syringe at day 0 (onset of the experiment), and at day 48 of the experiment. Five millilitres of blood were released into sample bottles containing ethyl dimethyl tetra acetic acid (EDTA) as an anticoagulant. The bottles were agitated thoroughly and analysed immediately for PCV and hb

concentration, as described by Jain (1993). Red blood cells (RBC), white blood cells (WBC), and the differential WBC counts were determined with the Neubauer haemocytometer after appropriate dilution (Lamb, 1981). The serum was then analysed with an automated spectrophotometer for total protein, aspartate aminotransferase (AST), ALT and urea. The total cost of feed intake is the sum of costs of *P. maximum* (kg) and the concentrate diet (kg). Feed cost per kg of weight gain was calculated by dividing the total feed cost by the total weight gain. Revenue per kg of weight gain was obtained by subtracting the feed cost/kg gain from the price per kg of live bodyweight (price per kg of live bodyweight = USD 2.07).

Data were subjected to one-way analysis of variance (ANOVA) in a completely randomized design as contained in SAS (1999). Means were separated using the new Duncan's (1955) multiple range test.

Table 1 Ingredient composition and chemical analysis of the experimental diets and *Moringa oleifera* leaf meal

Ingredients	Diets ¹			<i>Moringa oleifera</i> leaf meal
	MOLM0	MOLM50	MOLM100	
PKC, %	19.25	18.26	16.79	
Wheat offal, %	20.00	20.00	20.00	
Rice bran, %	40.00	37	35.00	
Oat meal, %	20.00	18.99	17.46	
Premix, %	0.25	0.25	0.25	
Salt, %	0.50	0.50	0.50	
MOLM, %	0	5.00	10.00	
Total	100	100	100	
Determined analysis				
Moisture, g/kg DM	40.3	105.6	26.0	40.0
Dry matter, g/kg	959.7	894.4	974.0	960.0
Crude protein, g/kg DM	209.2	255.8	276.6	314.7
Ether extract, g/kg DM	45.6	38.5	49.6	40.0
NDF, g/kg DM	55.6	43.1	65.1	355.3
ADF g/kg DM	35.5	28.4	37.5	253.0
Ash, g/kg DM	62.1	58.2	69.8	96.7

¹Diets: MOLM0: control diet; MOLM50: 50 g/kg *M. oleifera* leaf meal; MOLM100= 100 g/kg *M. oleifera* leaf meal; MOLM: *M. oleifera* leaf meal

²Ingredients: PKC: Palm kernel cake

³Determined analysis: NDF: Neutral detergent fibre, ADF: Acid detergent fibre, DM: dry matter

Results

Table 1 shows the proximate composition (g/kg) of *M. oleifera* meal (leaf plus twigs) and the experimental diets. *Moringa oleifera* plants (leaves and twig) contain 40.0 g/kg DM moisture, 960.0 g/kg dry matter, 315.0 g/kg DM crude protein, 40.0 g/kg DM ether extract, 355.0 g/kg DM neutral detergent fibre (NDF), 253.0 g/kg DM acid detergent fibre (ADF), and 97.0 g/kg DM total Ash. Moisture content in the experimental diets ranged from 26.0 to 106.0 g/kg DM. DM ranged from 893.0 to 973.0 g/kg DM. Crude protein ranged from 209.0 to 277.0 g/kg DM. Crude fibre ranged from 86.0 to 101.0 g/kg DM. Ether extract ranged from 39.0 to 49 g/kg DM. Total ash ranged from 58 to 690 g/kg DM. The performance characteristics of WAD goats fed MOLM-based supplements are presented in Table 2. Growth performance characteristics of the WAD goats were not ($P > 0.05$) influenced by MOLM inclusion in the supplements. However, the mean values obtained for final weight, weight gain and metabolic weight gain of goats fed 50 g/kg and 100 g/kg MOLM, respectively, were numerically higher than those fed the control supplement.

Table 2 Growth performance and feed conversion efficiency in West African Dwarf goats offered *Moringa oleifera* leaf meal based experimental supplements

Parameters	Diets ¹			SEM
	MOLM0	MOLM50	MOLM100	
Initial weight, kg	7.0	6.8	7.0	0.33
Final weight, kg	9.7	10.0	9.8	0.19
Total weight gain, kg	2.7	3.2	2.8	2.60
Metabolic weight, kg	1.9	2.1	2.2	0.15
Weight gain, g/day	55.7	63.3	66.7	6.62
Feed intake, g/day	259.3	266.9	249.7	26.57
Dry matter intake, g	248.9	225.3	243.2	20.00
Protein intake, g	52.1	57.6	67.3	7.20
FCR	4.7	4.2	3.74	0.40

¹Diets: MOLM0: control diet; MOLM50: 50 g/kg *M. oleifera* leaf meal; MOLM100: 100 g/kg *M. oleifera* leaf meal; MOLM: *M. oleifera* leaf meal

²FCR: feed conversion ratio

Table 3 shows the haematological parameters and serum chemistry of WAD goats fed MOLM at the end of the experiment. Moringa supplementation had no significant ($P > 0.05$) influence on the parameters except for ALT and urea. Goats offered supplements containing 0 and 100 g/kg MOLM had significantly higher ALT compared with those offered 50 g/kg MOLM. Inclusion of MOLM significantly increased blood urea concentration, with goats on 50 g/kg inclusion level having the highest mean value (1.53 mmol/l), followed by those fed 100 g/kg MOLM, while those with no MOLM had the lowest value (1.09 mmol/l).

Table 3 Haematological parameters and serum biochemical components of West African Dwarf goats offered *Moringa oleifera* leaf meal based supplements

Parameters ²	Diets ¹			SEM
	MOLM0	MOLM50	MOLM100	
PCV, %	22.7	21.3	26.3	1.39
Haemoglobin, g/dl	7.5	7.1	8.8	0.47
RBC, $\times 10^{12}$ g/dl	2.2	2.1	2.5	0.13
MCHC, g/dl	33.1	33.4	33.2	0.09
MCV, g/dl	34.7	34.4	34.3	0.1
MCH, fl	10.5	10.4	10.4	0.02
WBC, $\times 10^3$ /L	15.1	13.4	17.0	1.59
Total protein, g/dl	5.8	6.2	6.2	0.14
AST, IU/L	86.3	80.0	94.7	5.91
ALT, IU/L	20.0 ^a	15.7 ^b	19.7 ^a	0.84
Urea, mmol/l	1.09 ^c	1.5 ^a	1.3 ^b	0.65

^{a,b,c}Means in the same row with different superscripts are significantly different ($P < 0.05$)

¹Diets: MOLM0: control diet; MOLM50: 50 g/kg *M. oleifera* leaf meal; MOLM100: 100 g/kg *M. oleifera* leaf meal

²Parameters: PCV: packed cell volume, MCHC: mean corpuscular haemoglobin concentration, MCH: mean corpuscular haemoglobin, RBC: red blood cell, WBC: white blood cell, AST: aspartate aminotransferase, ALT: alanine transaminase, TPROT: total protein

Economic evaluation of the MOLM-based supplements is presented in Table 4. The estimated cost of *Panicum maximum* was USD 0.03/kg, while the costs of MOLM0, MOLM50, and MOLM100 were USD 0.18/kg, USD 0.17/kg, and USD 0.16/kg, respectively. The supplemented diets had significantly ($P < 0.05$) lower feed cost per kg of weight gain and higher returns per kg of gain than the control diet.

Table 4 Economic evaluation of diluting a commercial supplement with *Moringa oleifera* leaf meal

Parameters	Diets ¹			SEM
	MOLM0	MOLM50	MOLM100	
Cost of <i>Panicum maximum</i> /kg, USD	0.03	0.03	0.03	---
Cost of concentrate diet/kg, USD	0.18	0.17	0.16	---
Total cost of feed Intake, USD	0.21	0.20	0.19	---
Feed cost /kg gain, USD	0.09 ^a	0.08 ^b	0.07 ^c	0.001
Revenue per kg gain, USD	1.98 ^b	1.99 ^a	2.0 ^a	0.001

^{a,b,c} Means in the same row with different superscripts are significantly different ($P < 0.05$).

¹Diets: MOLM0: control diet; MOLM50: 50 g/kg *M. oleifera* leaf meal; MOLM100: 100 g/kg *M. oleifera* leaf meal

²Parameters: Feed cost/kg gain = total feed cost/total weight gain
Revenue/kg gain = price of 1 kg live bodyweight – feed cost /kg gain

Discussion

Moringa oleifera is one of the alternative forage protein sources. It compares well in nutrient composition, especially crude protein, with *Leucaena leucocephala* and *Gliricidia sepium* (Daramola *et al.*, 2005; Owusu *et al.*, 2008). *Moringa oleifera* supplementation has been reported to improve the growth performance of ruminants when supplemented as fresh fodder, hay, or as part of a concentrate diet (Sultana *et al.*, 2015; Kholif *et al.*, 2016; Jiwuba *et al.*, 2016). This is in contrast with the result of this present study, because the supplementation of MOLM had no influence on any of the growth parameters. However, the results of this study are in agreement with those reported (Asoalu, 2012) for goats fed *Leucaena leucocephala*, *G. sepium* and MOLM supplementation. In a related study, supplementing WAD rams with MOLM did not influence weight gain (Adegun & Aye, 2013). The numerically higher values in the group supplemented with MOLM show that MOLM could contribute towards better livestock performance in terms of bodyweight changes and high yield of good-quality products (Nouman *et al.*, 2014) as it contains an appreciable level of essential nutrients.

Although the supplemental levels of *Moringa* did not influence growth, it might be involved in other physiological functions such as immune response and osmotic balance, which were not measured in this study.

The immune system is one of the first body functions to be affected by an impaired nutritional status. Adequate nutrition is an important modulator of immune function and can often tip the balance between health and disease (NRC, 2002). The immune regulatory function of *Moringa* was demonstrated through increased blood urea concentration in the supplemented groups. Elevated levels of blood urea are a function of a high level of dietary protein, while blood serum antioxidant activity correlates positively with blood urea concentration (Marciniak *et al.*, 2005). The antioxidant activity of urea is important in boosting the immunity of goats through the elimination of excess reactive oxygen molecules (pro-oxidants) that may impair their immune functions. Simovi *et al.* (2002) reported that a decreased level of blood urea elevates oxidative stress and predisposes the animals to various diseases. In addition, blood urea is an indicator of normal kidney and liver functions. Results from this study show that *Moringa* supplementation did not impair kidney and liver functions (Suckow *et al.*, 2012). Increased blood urea concentration can also be useful in urea recycling in ruminants, which is important for growth maintenance. It has been reported that diets, restriction of feed and drug administration may affect blood level of ALT (Evans, 2009). The ALT was within the normal physiological range reported by Oni *et al.* (2012) and Daramola *et al.* (2005), which further showed that *Moringa* had no negative impact on goat liver.

The lack of variation in haematological parameters across dietary treatments in the present study is in agreement with the studies of some researchers (Daramola *et al.*, 2005; Fadiyimu *et al.*, 2010), who reported that the haematological parameters of WAD sheep fed *M. oleifera* as a supplement to *P. maximum* did not differ. However, most of these parameters were within the normal reference range for clinically healthy goats

(Daramola *et al.*, 2005; Merck, 2011; Asaolu, 2012). The normal range of PCV values, and the numerical increase observed in those offered MOLM supplementation, suggested that inclusion of Moringa in goat diets might increase the recovery rate of goats in the event of an infection (Ganong, 2005).

The inclusion of MOLM in the commercial supplement did not negatively affect blood parameters in this study. This may be because of a tolerable level of anti-nutrients in Moringa (Anhwange *et al.*, 2004; Sánchez-Machado *et al.*, 2010). The numerically higher values obtained for most of the blood parameters were within the normal blood range for healthy goats, indicating that *M. oleifera* could safely be included in goat diet (Oluwole-Banjo *et al.*, 2001; Jibowu *et al.*, 2017). The significantly lower feed cost per gain corroborates Mousa & El-Shabrawy's (2003) work on Damascus kids. It is also in line with other reports on lambs (Mousa, 2011). This indicates that each kilogram of weight gain at higher levels of Moringa inclusion is produced at a lower cost and thus yields higher revenue and profit. Plant leaf meal and tree foliage have been reported to be cost-effective protein sources that can be used in ruminant feeding (Alsersy *et al.*, 2015; Kholif *et al.*, 2015; Salem *et al.*, 2015). In the tropics, they can be obtained at relatively no cost by the roadside, and at compounds and backyards of smallholder farmers.

Conclusions

The inclusion of MOLM in the conventional supplement up to 100 g/kg DM level had no adverse effect on the nutritional status, growth performance, and health of WAD goats. However, MOLM supplementation at this level reduced the cost of production per kilogram of weight gain, resulting in higher revenue.

Authors' Contributions

AOY and SOI designed the study and sample collection and data analysis were done by AOY. VM and AOY participated in results, statistics and interpretation. AOY wrote the draft manuscript, while VM and SOI edited it.

Conflict of Interest Declaration

The authors would like to confirm that there is no conflict of interest in the course of this research.

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