Journal of Advances in Biology & Biotechnology
8(3): 1-9, 2016; Article no.JABB.27390
ISSN: 2394-1081

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Performance, Apparent Nutrient Digestibility and Cost Benefit of West African Dwarf Goats Fed Dietary Levels of *Moringa oleifera* Leaf Meal

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Authors' contributions

This work was carried out in collaboration between all authors. Author PCJ designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KI and NON managed the analyses of the study and the literature searches. Author SIU managed the economic evaluation and analysis of the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JABB/2016/27390
Editor(s):
(1) Joana Chiang, Department of medical laboratory Science and Biotechnology, China Medical University, Taiwan.
Reviewers:
(1) I. A, Amata, Delta State University, Asaba Campus, Delta State, Nigeria.
(2) Josephine Kasolo, Makerere University College of Health Sciences, Uganda.
Complete Peer review History: http://www.sciencedomain.org/review-history/15656

Original Research Article

Received 31st May 2016
Accepted 18th July 2016
Published 4th August 2016

ABSTRACT

Aims: To determine the performance, apparent nutrient digestibility and cost benefit of West African Dwarf goats fed dietary levels of *Moringa oleifera* leaf meal diets.
Study Design: Completely randomized design and Latin square design.
Place and Duration of Study: At the Sheep and Goat unit of the Teaching and Research farm of Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria, between November 2013 and February 2014.
Methodology: 36 West African Dwarf Goats were used for this study. Four diets were formulated such that diets T1, T2, T3 and T4 contain MOLM at 0%, 5%, 10% and 15%, respectively. Other

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ingredients remained constant for the four diets. The diets were offered to matured goats, which were randomly divided into four (4) groups of 9 goats each, with three goats constituting a replicate in a completely randomized design pattern. Each animal received the designated diet on 3% body weight basis in addition to *Panicum maximum*.

Results: Results showed that average daily feed intake differed significantly (P<0.05) with goats fed 15% MOLM diets having the highest intake (495.19 g/d). Similarly average daily weight gain was (p<0.05) highest (46.00 g/d) for T_4 animals. Average daily dry matter intake also differed significantly (P<0.05) and the values ranged between 395.14 to 448.69 g/day and increased with increasing levels of *Moringa oleifera* leaf meal. Feed conversion ratio differed significantly (P<0.05) and was however best for T_4 animals (10.77). Apparent nutrient digestibility coefficient; dry matter, crude protein, crude fibre, ether extract and ash differed significantly (P<0.05) for the treatment groups with diet T4 having relatively better values. Cost benefit was influenced (p<.0.5) with T4 animals having better income (2.05) on investment.

Conclusions: Diet T_4 promoted the best relative performance among the treatment diets and is therefore recommended for production of West African Dwarf goat.

Keywords: Growth performance; feed intake; nutrient digestibility; cost benefit; West African dwarf goat; Moringa oleifera leaf meal; alternative feed stuff.

ABBREVIATIONS

MOLM; Moringa oleifera leaf meal, PM; Panicum maximum, Average daily DMI; Average daily dry matter intake, DMI% BWT Concentrate; dry matter intake as percentage of body weight for concentrate, DMI% BWT Forage; dry matter intake as percentage of body weight for forage, Total dry matter intake % BWT; Total dry matter intake as percentage of body weight, WAD: West African Dwarf .

1. INTRODUCTION

Goat is one of the most important domestic livestock to man. It plays an important socio-economic role and forms very important part of the cultural life in most developing countries. Goats are reared mostly at subsistent level in most West African countries. They are usually left on extensive system to roam and cater for their own feed. According to [1], these feed resources include natural pastures, crop residues and fibrous agro-industrial waste products which have high fibre and low protein with organic matter digestibility between 30–45%. During the dry season, the natural pastures and crop residues available for ruminants are highly fibrous and deficient of most essential nutrients required for increased rumen microbial fermentation and improved performance of the host animal. This therefore will result in weight loss, low birth weights, lowered resistance to disease, and overall poor performance of the animal. In response to this, the usual practice has been to supplement livestock diets with protein rich conventional ingredients such as groundnut cake soybean meal and cotton seed cake [2]. This has resulted in improved performance of the host animal, but unfortunately, these supplements are usually not fed due to the scarcity and high cost attached to them.

However, a cheaper alternative means of enhancing utilization of low quality forage is by supplementation with the foliages of high nitrogen multipurpose trees [3]. Studies have shown that multipurpose trees can be used as cheap protein supplements which can improve voluntary feed intake, digestibility and general performance of animals fed low quality feeds [4]. The leaves of *Moringa oleifera* plants have been widely reported with high nitrogen profile.

Moringa oleifera is known as miracle tree in English and Okochi egbu in Igbo language. *Moringa oleifera* plant has the ability of being available all year round because of its drought resistance, persistence, vigorous growth and the ability to re-grow fast. The use of *Moringa oleifera* for livestock especially in developing countries is seen as a measure for sustainable livestock production due to its numerous advantages in foliage yield and nutrient balance. Leaf meals from *M. oleifera* will not only provide protein sources but also some essential vitamins, minerals and carotenoids to the animals. *Moringa oleifera* leaves are known to be very poor in anti-nutritional factors and have been used in ruminants [5] and in monogastric feeding. Besides being rich in carotene, ascorbic acid and iron, *M. oleifera* leaf is also rich in two amino acids; methionine and cysteine which are usually deficient in other feed resources [6]. Despite the high nutritive value of *M. oleifera*, there is little information available on the use of this unconventional feed resource, especially as a leaf meal in the formulation of concentrate diets. This experiment was therefore designed to evaluate the growth performance, feed intake, apparent nutrient digestibility and cost benefit of West African Dwarf goats fed dietary levels of *Moringa oleifera* leaf meal diets.

2. METHODOLOGY

2.1 Location of the Experiment

The experiment was conducted at the Sheep and Goat unit of the Teaching and Research farm of Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. The study area is located at latitude 05°28 [1] North and longitude 07°31 [1] East and lies 122 meters above sea level. Umudike lies within the Tropical rainforest zone, characterized by average annual rainfall of 2177 mm in 148-155 rain days. Average ambient temperature was 25.5°C with minimum and maximum temperatures of 22°C and 29°C respectively. Relative humidity ranged between 76-87%.

2.2 Sources and Processing of Experimental Material

Fresh *Moringa oleifera* leaves used for the trial were obtained from Ihitte Uboma and Obowo Local government areas, both in Imo State, Nigeria. *Moringa oleifera* leaves were subsequently air-dried to about 10% moisture content before milling and used at different levels in the formulation of *Moringa oleifera* leaf meal diets.

2.3 Management of Experimental Animals

Thirty six West African Dwarf (WAD) goats of about 10 – 12 months of age and averaged 8.43 kg were purchased and quarantined for 21 days and subsequently fed for a preliminary period of 21 days. The ration fed was the control diet (Table 1) in addition to fresh *Panicum maximum* for acclimatization. This was done to build up each animal's appetite for concentrate diet. Prior to the trial, the animals were dewormed and sprayed against external parasites.

2.4 Experimental Diets

Experimental diets designated as T1, T2, T3 and T4 were formulated from cassava peel, brewers dried grain, palm kernel meal, maize offal, *Moringa oleifera* leaf meal, bone meal and salt. Diet T1 served as a positive control and contained 0% of *Moringa oleifera* leaf meal. Diets T2, T3 and T4 contain 5%, 10% and 15% levels of *Moringa oleifera* leaf meal respectively as illustrated in Table 1.

2.5 Growth Trial

After the preliminary feeding period, the 36 West African Dwarf goats were randomly divided into four (4) groups of nine (9) animals each. The groups were randomly assigned the 4 treatment diets (T1, T2, T3, and T4) in a Completely Randomized Design. The animals were housed individually in well ventilated cement floored pens equipped with feeders and drinkers. Each animal received the designated treatment diet in the morning for 90 days. Feed offered was based on 3% body weight per day; the animals in addition were fed 2 kg fresh *Panicum maximum* later in the day. Regular access to fresh drinking water was made available. Feed offered and refused were recorded on a daily basis. Initial weights of the animals were taken at the beginning of the trial and weekly subsequently.

Table 1. Gross composition of the experimental diets

Ingredients	**Dietary levels (%)**			
	T1	**T2**	**T3**	**T4**
Maize offal	30.00	30.00	30.00	30.00
Cassava peel meal	20.00	20.00	20.00	20.00
Palm kernel cake	22.00	22.00	22.00	22.00
Brewer's dried grain	25.00	20.00	15.00	10.00
Moringa oleifera leaf meal	0.00	5.00	10.00	15.00
Bone meal	2.00	2.00	2.00	2.00
Salt	1.00	1.00	1.00	1.00
Total	**100**	**100**	**100**	**100**

2.6 Apparent Nutrient Digestibility Coefficient

Each treatment group comprising four West African Dwarf goats were transferred to and housed in separate metabolism cages with facilities for collecting faeces and urine. Each animal was fed one of the four experimental diets (Table 1) in a 4 x 4 Latin square design. During phase 1 which lasted for 21 days, each animal received 1 kg of one of the 4 experimental diets. Fresh water was offered *ad libitum* to each animal daily. Daily voluntary feed intake was determined by weighing the quantity offered and refused. Total faeces and urine voided by the experimental animals were collected during the last 7 days (21st – 28th). In phases 2-4 each animal was offered each of the remaining 3 experimental diets in rotational periods of 28 days each. The last 7 days in each of the feeding period, was also used for total urine and faecal collection. Total faeces were collected in the mornings before feeding and watering during days 21–28 of each period. Faecal samples were collected and bulked for each animal. A sub sample from each animal was dried in forced draft oven at 100-105℃ for 48 hours and used for dry matter determination. Another sample was dried at 60℃ for 48-72 hours for determination of proximate composition. Apparent coefficient digestibility for nutrients was determined as given below:

$$\frac{\text{Nutrient in feed- nutrient in faeces}}{\text{Nutrient in feed}} \times \frac{100}{1}$$

2.7 Cost Benefit Ratio

The prevailing market prices of the feed ingredients at the time of the experiment were used to estimate the unit cost of the experimental diet. The variable cost of feeding the goats considered as the cost of the feeds and all other costs (i.e. labour, capital investment and housing) were the same for all the treatments. The cost of processing the MOLM was included as the feed cost. Feed cost per kilogramme, cost per kilogramme of weight gain and cost benefit ratio were calculated.

2.8 Analytical Procedure

All feeds samples were analyzed for proximate compositions using the method of [7].

2.9 Statistical Analysis

The results were analyzed using the Special Package for Social Sciences Window 17.0. One - way analysis of variance (ANOVA) was employed to determine the means and standard error. Differences between means were separated using Duncan's new multiple range test.

3. RESULTS AND DISCUSSION

3.1 Proximate Compositions

The proximate composition of the experimental diets, *Moringa oleifera* leaf meal (MOLM) and *Panicum maximum* used in this study are presented in Table 2. The proximate composition of the MOLM showed a high level of dry matter (DM), Metabolizable energy (ME), ether extract (EE) and crude fibre (CF), crude protein (CP) and relative low values of ash. This is in agreement with the reports of [8-10], for the same forage. The crude protein value of 23.24% obtained for MOLM in this present study favourably compared with the values of 23.27% and 22.2% reported by [8,9] respectively. However, higher values of 26.74% and 28.8% were reported by [11,10] respectively for MOLM. The differences in the crude protein values could be due to the age of the plants, the stage of development when the leaves were harvested, location, season, soil type, the dry matter content and processing method used.

The DM values of the treatment diets compared with the control, but however did not show any specific pattern. The crude protein, crude fibre and ash content of the test diets were relatively higher than the control diet and the concentration tended to increase with increasing levels of MOLM in the diets; the MOLM inclusions in the test diets could be responsible for the increases in crude protein contents observed, since browse plants maintain relatively high crude protein content during the dry season. However, the crude protein content of all the diets were higher than 8% necessary to provide minimum nitrogen required by micro-organisms to support basic rumen activities [12].

3.2 Growth Performance

Table 3 shows the growth performance of West African Dwarf goats fed graded levels of *Moringa oleifera* leaf meal diets. The diets influenced positive weight changes ($P<0.05$) among the experimental groups. Average daily feed intake differed significantly ($P<0.05$) among the treatment groups. Value for the animals fed control diet (T1) compared ($P>0.05$) with those of T2 and T3, but however differed ($P<0.05$) significantly from that group fed T4 diet. The average daily feed intake of the animals varied from 448.26 – 495.19 g/day for T1 and T4 respectively. Similarly, the average daily dry matter intake varied from 395.14 – 448.69 for T1 and T4 respectively. Total feed intake, dry matter intake as percentage of body weight for concentrate, dry matter intake as percentage of body weight for forage and total dry matter intake, however were not influenced (P>0.05) by the treatment diets; the values however, increased from T1 to T4. Average daily dry matter intake was significantly (P<0.05) affected by the treatment diets, with T1 having the lowest value of 395.14 g/day as against 411.47, 442.82 and 448.69 g/day for T2, T3 and T4 respectively. Dry matter intake is an important factor in the utilization of feed by ruminants. The improvement in intake with *Moringa oleifera* leaf meal diets is in agreement with the results of [13] who fed enzyme fortified raw Moringa Seed (*Moringa oleifera*) to broilers. The significant dry matter intake obtained in the diet containing 15% *Moringa oleifera* leaf meal may be due to its higher protein quality, greater palatability and higher protein content of the diet. This is in line with the report of [14] that diets with higher protein content increases intake.

Goats that received T4 diet had highest average daily gain of 46.00 g/day. Treatments had no significant (P>0.05) effect on final body weight, however values obtained for total weight gain and average daily weight gain were significantly (P<0.05) influenced by treatments diets. The respective values for T3 (4.02 kg; 44.66 g) and T4 (4.14 kg; 46.00 g) were similar (P>0.05) but however higher (P<0.05) than the values obtained for T1 (2.90 kg; 32.22 g) and T2 (3.15 kg; 35.00 g); these latter values did not differ (P>0.05) from each other. The total weight gain and the average daily weight gain of West African Dwarf goat for the treatment groups were significantly (*P*<0.05) different. The total weight gain values among the experimental animals varied from 4.14 kg to 2.90 kg for T4 and T1 respectively. The average daily weight gain values for the West African Dwarf goat varied from 46.00 g/day to 33.22 g/day for T4 and T1 respectively. The marked variation in weight gain by the animals fed the test diets may be attributed to *Moringa oleifera* leaf meal due to its high composition of the essential nutrients and high dry matter content especially during the dry season. The superior weight gains exhibited by animals on T4 over T1 may also be attributed to the high feed intake and feed utilization of the animals on T4 relative to T1 diet, since voluntary feed intake of an animal is directly related to the body weight changes.

Feed conversion ratio differed (p<0.05) significantly, with T4 having relatively the best value (10.77). T1 and T2 values were significantly (p<0.05) higher than T3 and T4; even though there was no statistical (p>0.05) difference between the latter, T4 had the least feed conversion ratio indicating a better feed conversion ratio. The superior feed efficiency of diets T3 and T4 over the other diets is a reflection of the observed higher feed utilization and indeed higher growth rates of goats fed the respective diets. The present value however compared favourably with the observations of [15] for West African Dwarf goats. Factors which influence feed conversion ratio among other include breed, age and sex of animals as well as nutrition and environment.

3.3 Apparent Nutrient Digestibility

The apparent nutrient digestibility of West African Dwarf goats fed the graded levels of *Moringa oleifera* leaf meal is presented in Table 4. The digestibility of dry matter, crude protein, crude fibre, ash and ether extract were influenced (p<0.05) by treatment diets. However, nitrogen free extract was not influenced (P>0.05) by the

Table 2. Proximate compositions (% DM basis)

Parameters (%)	Dietary levels				MOLM	PM
	T1	T2	T3	T4		
Dry matter	88.15	90.47	90.92	90.61	87.90	34
Crude protein	17.07	18.79	19.38	20.20	23.24	7.21
Crude fibre	16.83	17.93	18.21	18.63	13.16	19.16
Esther extract	15.22	15.56	15.94	16.02	4.15	1.92
Ash	4.19	4.76	4.25	4.56	6.21	1.70
Nitrogen free extract	33.84	33.43	32.71	31.20	41.14	4.01
Metabolizable energy (Kcal/kg)	3075.55	3150.30	3178.05	3160.70	2606.05	555.90

MOLM = Moringa oleifera leaf meal
PM = Panicum maximum

Table 3. Growth performance of West African Dwarf Goats fed graded levels of *Moringa oleifera* leaf meal

Parameter	T1	T2	T3	T4	SEM
Initial weight (kg)	8.33	8.47	8.40	8.53	0.14
Final weight (kg)	11.23	11.62	12.42	12.67	0.28
Total weight gain (kg)	2.9 0^{b}	3.15^{b}	4.02^{a}	4.14^{a}	0.20
Average daily weight gain (g/day)	32.22^{b}	35.00^{b}	44.66^{a}	46.00^{a}	2.22
Average daily feed Intake (g/day)	448.26^{b}	454.81^{ab}	487.04^{ab}	495.19^{a}	8.05
Total feed intake (kg)	40.34	40.93	43.83	44.57	1.36
Average daily DMI (g/day)	395.14^{b}	411.47^{ab}	442.82^{a}	448.69^{a}	8.11
DMI % BWT concentrate (%)	2.60	2.63	2.70	2.69	0.03
DMI % BWT forage (%)	0.69	0.71	0.72	0.73	0.05
Total dry matter intake % BWT (%)	3.29	3.34	3.42	3.42	0.05
Feed conversion ratio	13.90^{a}	12.99^{a}	10.90^{b}	10.77^{b}	0.48

$^{a-b}$, means on the same row with different superscripts are significantly different at p<0.05)
Average daily DMI = Average daily dry matter intake
DMI% BWT Concentrate = dry matter intake as percentage of body weight for concentrate
DMI%BWT Forage = dry matter intake as percentage of body weight for forage
Total dry matter intake % BWT = Total dry matter intake as percentage of body weight

diets. Crude protein digestibility coefficient followed a similar trend as the dry matter; increasing from T1 – T4. Crude fibre coefficients digestibility followed an inconsistent trend. Crude protein and crude fibre were least digested in T1 (56.71%), (67.58%) and best digested in T4 (77.76%) and T3 (74.70%), respectively. Ether extract and ash differed significantly ($p<0.05$) among the treatment groups. However, T1 and T2 were similar ($p>0.05$) but differed significantly ($p<0.05$) from the values obtained for T3 and T4 for Ether extract digestibility coefficients. The Nitrogen free-extract coefficients of digestibility were not influenced ($p>0.05$) by diets but nevertheless decreased from the control diet T1 to T4. The dry matter contents of the diets were digested better ($p<0.05$) in the test diets than the control. Dry matter digestibility coefficients in the diets T3 and T4 were similar ($p>0.05$) but differed ($p<0.05$) from the values of 56.20% and 53.02% obtained respectively for diets T2 and the control. Dry matter digestibility increased as the levels of *Moringa oleifera* leaf meal increased in the diets. This observation is in consonance with the findings of [16] (59.00%) and [17] (63.02%) respectively. The high dry matter digestibility of T4 and T3 animals relative to T1 and T2 could be attributed to high crude protein content and higher intake of animals fed the relative diets. This could be explained by the fact that feeds rich in protein content promotes high microbial population and facilitates rumen fermentation [18]. The higher digestibility coefficient of crude protein obtained among the test diets indicated that the dietary protein was better utilized by the animals fed the test diet relative to control. This perhaps could be due to higher level (15%) of *Moringa oleifera* leaf meal in T4 diet which may have influenced the highest digestibility recorded for T4, since dietary protein [19] have been shown to enhance digestibility. This is in agreement with the findings of [20] who reported that protein digestibility decreases with decreasing levels of dietary protein.

The results of crude fibre digestibility in this study showed that crude protein content of diets was positively correlated with the crude protein digestibility and crude fibre digestibility. Crude protein and crude fibre are components of dry matter and therefore any factor that affects the dry matter of a feed would similarly affect the crude protein and crude fibre component of the same feed [19]. This may explain why the digestibility coefficient of crude protein and crude fibre increased from treatment T1 to T4, in the same pattern with dry matter. The higher crude fibre digestibility coefficient of T3 and T4 may suggest an increase in the activities of fibrolytic bacteria in the rumen probably as a result of the availability of essential nutrients especially protein, energy, vitamins and minerals which are evident in the test ingredient to enhance microbial growth and multiplication. [21] reported ash digestibility values ranging from 60.34-75.82%, which were higher than the coefficients obtained in this study; the present values however compared favourably with the range of values (31.96-54.43%) reported by [22].

Table 4. Apparent digestibility coefficient of West African Dwarf Goat fed graded levels of *Moringa oleifera* leaf meal diets

Parameters (%)	Diets				SEM
	T1	T2	T3	T4	
Dry matter	53.02[c]	59.20[b]	65.03[a]	69.70[a]	0.72
Crude protein	56.71[c]	72.55[b]	76.70[a]	77.76[a]	1.07
Crude fibre	67.58[c]	56.20[b]	74.70[a]	73.93[a]	0.77
Ether extract	92.17	92.73	89.22	89.92	0.43
Nitrogen free extract	42.28	43.96	43.97	43.22	0.79
Ash	35.99[c]	40.65[b]	45.05[a]	42.80[ab]	1.10

[a-c], means on the same row with different superscripts are significantly different at (p<0.05)

Table 5. Cost benefit of West African Dwarf goats fed graded levels of *Moringa oleifera* leaf meal

Parameters	Diets				SEM
	T1	T2	T3	T4	
Cost/100 kg feed (^)	3555.00[a]	3505.00[b]	3455.00[c]	3405.00[d]	17.03
Cost/kg feed (^)	35.55[a]	35.05[b]	34.55[c]	34.05[d]	1.24
Total feed consumed (kg)	40.34	40.93	43.83	44.57	1.36
Total cost of feed (^)	1434.09[b]	1434.60[b]	1514.33[a]	1517.61[a]	13.43
Total weight gain (kg)	2.90	3.15	4.02	4.14	0.30
Feed cost/weight gain	494.51[a]	455.43[b]	376.70[c]	366.57[c]	16.67
Cost/kg live weight	750	750	750	750	0.00
Cost benefit ratio	1:1.52	1:1.165	1:1.99	1:2.05	

[a-d], means on the same row with different superscripts are significantly different at (p<0.05)

3.4 Cost Benefit

The cost benefit ratio of West African Dwarf goats fed graded levels of *Moringa oleifera* leaf meal diets are presented in Table 5. The cost of production per 100 kg feed differed (P<0.05) significantly within the treatment groups and tended to decrease with increasing levels of MOLM inclusions in the diets. Cost of production per kilogramme of feed also differed (p<0.05) among the treatment groups. Cost benefit ratio was best for animals on T4 diet and differed (p<0.05) among the treatments. Increasing levels of MOLM lowered feed cost/kg significantly (P<0.05). As the level of inclusion of MOLM in the diets increased from 0% (T1) to 15% (T4), the feed cost/kg for each treatment group decreased with increasing levels of MOLM. The values for feed cost per weight gain was lowest for the goats fed T4 diet 15% MOLM (^366.57), however this unit cost differed (P<0.05) significantly from the corresponding unit cost of ^455.43 and ^494.57 derived from the goats fed T1 (5% *Moringa oleifera* leaf meal) and the control diets. Cost benefit ratio showed significant (p<0.05) differences with T4 having the best ratio. This was agreement with the results of earlier studies by [23] who reported that the need to lower feed cost in order to produce affordable meat and other animal products for the populace cannot be over-emphasized in the face of dwindling standard of living. The result demonstrates the qualitative benefits and financial returns of using MOLM diets; with T4 having the highest ratio and T1 has the lowest value. This entails an expected benefit of ^2.05 for every ^1 in cost for T4 diet. This is in agreement with [24] who reported that inclusion of *Moringa oleifera* in the diet of rabbits reduces the cost of feed. This result also suggest that the optimum level of inclusion of *Moringa oleifera* leaf meal in the diet of goats may not have been attained and perhaps incremental level beyond 15% inclusion may still yield higher cost benefit ratio beyond the value recorded for T4 in this trial. That, however, would be determined by future investigation.

4. CONCLUSION

The inclusion of *Moringa oleifera* leaf meal in the diets of West African Dwarf goats generally enhanced dry matter intake, average daily feed intake, average daily weight gain, feed conversion ratio, apparent nutrient digestibility and cost benefit ratio when compared to the control. Specifically however, the diet containing

15% *Moringa oleifera* leaf meal inclusion had the least cost of production (produced the cheapest goat meat). The nutrients in the diet were also relatively better digested. The rich nitrogen source of *Moringa oleifera* leaf meal can further be exploited to boost sustenance and production of West African Dwarf goats especially during periods of scarcity when fodder quality and quantity are low. Incorporation of *Moringa oleifera* leaf meal in goat's diet provided nourishable supplement for goats. This way more meat and kid crops will be realized making animal protein available and affordable.

ETHICAL APPROVAL

This paper followed all the guidelines for the care and use of laboratory animal model of the Michael Okpara University of Agriculture, Umudike, Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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