ISSN 1996-3351

# Asian Journal of Biological Sciences

Knowledgia
SCIENTIFIC
A Place to Publish Outstanding Research

http://knowledgiascientific.com

OPEN ACCESS Asian Journal of Biological Sciences

ISSN 1996-3351
DOI: 10.3923/ajbs.2019.656.663

# Research Article
# Potential of *Moringa oleifera* Leaf Meal to Replace Soybean Meal in Rabbit Diets and its Influence on Production Parameters

[1]Peter-Damian Chinonso Jiwuba and [2]Ifeanyi Princewill Ogbuewu

[1]Department of Animal Production Technology, Federal College of Agriculture, P.M.B.7008, Ishiagu, Ebonyi State, Nigeria
[2]Department of Animal Science and Technology, Federal University of Technology, P.M.B. 1526, Owerri, Nigeria

## Abstract

**Background and Objective:** The increased cost of major protein concentrates has hindered the growth of animal production in the tropics. The study aimed to ascertain the effect of feeding *Moringa oleifera* leaf meal (MOLM) on growth response, carcass value and economic indices of growing rabbits. **Materials and Methods:** Forty-eight growing rabbits were randomly divided into four dietary groups ($T_1$-$T_4$) of 12 animals each, with four rabbits making a replicate. Rabbits in each treatment were allocated to one of the diets having MOLM at 0, 10, 20 and 30% in a completely randomized design. **Results:** The MOLM was observed to be abundant in essential nutrients. Rabbits on $T_4$ diet had a significantly higher intake (89.84 g/day). Rabbits on $T_3$ and $T_4$ diets had the best ADWG and FCR. Cost benefit was influenced ($p<0.05$) with $T_4$ animals yielding a higher income of N6.85 per N1 invested. The ADWG (21.99 g/day), ADFI (90.19 g/day), FCR (4.06) and dressing percent (69.63%) were optimized at 35.96, 48.755, 32.71, 32.83 and 31.95% MOLM, respectively. **Conclusion:** It is, therefore, concluded that optimizing MOLM level in the diet of growing rabbits could be helpful in improving their productivity.

Key words: *Moringa* leaf meal, rabbits, production parameters, quadratic function, optimization

Citation: Peter-Damian Chinonso Jiwuba and Ifeanyi Princewill Ogbuewu, 2019. Potential of *Moringa oleifera* leaf meal to replace soybean meal in rabbit diets and its influence on production parameters. Asian J. Biol. Sci., 12: 656.663.

Corresponding Author: Ifeanyi Princewill Ogbuewu, Department of Animal Science and Technology, Federal University of Technology, P.M.B. 1526, Owerri, Nigeria Tel: +27631307576



Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Rabbit production as a means of reducing the shortage of animal protein intake in developing countries is neglected. Due to the increasing cost of the conventional animal proteins, attention has been channeled to rabbit farming as a cheap source of high quality animal protein source. In sub-saharan Africa, Nigeria and Ghana are the main producers of rabbit followed by the Democratic Republic of the Congo, Cameroon, Cote d'Ivoire and Benin[1]. Today, rabbit meat has assumed prominence globally due to its low cholesterol content and excellent protein value. This growing popularity of rabbit meat may in part be attributed to its high growth rate and fecundity and the ability of the rabbit to survive on a wide variety of feedstuffs.

However, the high cost of commercial feeds undermines rabbits in expressing their full potential. This may be due to the high cost of protein and energy concentrates and little knowledge about the efficient utilization of unconventional protein sources by livestock farmers. Protein is very important for improving livestock performance and needs to be adjusted with respect to the requirements of the animal in addition to the balance of other nutrients available[2]. This is because diets are formulated to enhance the performance of animals by supplying the required nutrients without compromising their physiological and health status. One possible source of cheap protein is the leaf meals of some tropical plants[2]. Leaf meals are known to provide protein, vitamins, minerals and oxycarotenoids[3,4]. Despite, the importance of leaf meals in animal feed, it has been noticed that leaf meals harbour a wide range of anti-physiological agents like tannins, hemagglutinins, saponins and prosopine[5] when not properly processed.

The use of leaf meals of tropical plants such as *Moringa oleifera* to improve animal performance and optimize profit has been reported by Jiwuba *et al.*[6]. *Moringa oleifera* is one of the cultivated species of the genius *Moringa* and is low in tannins, but rich in essential nutrients[7,8]. It is known as the miracle tree in English language and *Okochi egbu* in Igbo language[9]. The plant yield about 24 Mt of total dry matter (DM) per hectare per year[10]. Leaves and immature pods of *Moringa* plants are used in the preparation of humans' food due to their high vitamins (A, B and C), sulphur-containing amino acids and minerals (calcium, iron and phosphorus) and carotene content[7].

Currently, there is scanty of information on the production parameters of growing rabbits fed diets containing MOLM in a hot tropical condition. Therefore, the objective of the study was to determine the nutrient composition of MOLM and the effect of its inclusion on growth rate, carcass and organ weight characteristics and cost/benefit evaluation of growing rabbits. The optimal MOLM inclusion rate that significantly enhanced the production outcomes (growth rate, carcass and organ weight) in growing rabbits will also be modelled using quadratic optimization function.

## MATERIALS AND METHODS

**Location of experiment and ethical approval:** The research was carried out at the Rabbit Unit, Federal College of Agriculture, Ishiagu, Ivo Local Government Area of Ebonyi State, Nigeria during the months May-June, 2017. The College is located about 3 km away from Ishiagu main town. The College is situated at latitude 5.56°N and longitude 7.31°E, with a mean rainfall of 1653 mm and a prevailing temperature condition of 28.50°C and relative humidity of about 80%. The rabbits were raised in line with the guidelines of the Institution's Ethics Committee on the use of Animals.

**Sources and processing of experimental material:** Fresh leaves of *Moringa oleifera* were harvested within the College environment and air dried for some days to a moisture content of about 10%. The dried leaves were processed and milled. The MOLM was analyzed for proximate compositions using the standard method[11].

**Experimental diets:** Four diets, $T_1$, $T_2$, $T_3$ and $T_4$ were formulated from maize, wheat offal, soybean, fish meal, palm kernel cake, *Moringa oleifera* leaf meal, bone meal, limestone, vitamin premix, methionine, lysine and common salt. Treatment one ($T_1$) did not contain the test ingredients, thereby serving as the positive control. The experimental diets were formulated such that *Moringa oleifera* leaf meal was included at the levels of 0, 10, 20 and 30% for $T_1$, $T_2$, $T_3$ and $T_4$, respectively as presented in Table 1. Experimental diets were analyzed for proximate compositions using the standard method of AOAC[11] and metabolisable energy (ME) calculated using the formula:

$$\text{ME} = 3.5 \times \text{crude protein} + 8.5 \times \text{crude fat} + 3.5 \times \text{nitrogen free extract} \times 10$$

**Experimental materials and management:** Forty-eight growing rabbits were randomly divided into four experimental groups of 12 animals each, with four rabbits constituting a replicate. The four treatment groups were assigned the four experimental diets in a Completely Randomized Design. Each rabbit received an assigned diet for 41 days. The animals were provided with feeders and drinkers. Each animal was

Table 1: Composition of the experimental diets

| | Dietary MOLM inclusion levels (%) | | | |
|---|---|---|---|---|
| Ingredients | $T_1$ (0%) | $T_2$ (10%) | $T_3$ (20%) | $T_4$ (30%) |
| Maize | 37.00 | 37.00 | 37.00 | 37.00 |
| Wheat offal | 9.00 | 9.00 | 9.00 | 9.00 |
| Palm kernel cake | 10.00 | 10.00 | 10.00 | 10.00 |
| Fish meal | 3.00 | 3.00 | 3.00 | 3.00 |
| Soybean meal | 35.00 | 25.00 | 15.00 | 5.00 |
| MOLM | 0.00 | 10.00 | 20.00 | 30.00 |
| Bone meal | 2.00 | 2.00 | 2.00 | 2.00 |
| Limestone | 1.50 | 1.50 | 1.50 | 1.50 |
| *Vitamin/mineral premix | 1.50 | 1.50 | 1.50 | 1.50 |
| Common salt | 0.50 | 0.50 | 0.50 | 0.50 |
| Lysine | 0.25 | 0.25 | 0.25 | 0.25 |
| Methionine | 0.25 | 0.25 | 0.25 | 0.25 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 |

*To provide the following per kilogram feed: Vitamin A: 12100 IU, Vitamin D3: 2500 IU, Vitamin E: 8 mg, Vitamin K: 2 mg, Vitamin B1: 3 mg, Vitamin B2: 5 mg, Niacin: 15 mg, Pantothenic acid: 6 mg, Folic acid: 4 mg, Manganese: 8 mg, Zinc: 0.05 mg, Iron: 29 mg, Copper: 3 mg, Iodine: 1.2 mg, Selenium: 0.16 mg and Cobalt: 2 mg

vaccinated against the prevalent diseases and was quarantined for 21 days before the commencement of the experiment. They were also dewormed and given acaricides prior to the experiment. Regular access to fresh drinking water was made available. Feed offered and refusal was recorded on a daily basis. Initial weights of the animals were taken at the beginning of the trial and weekly subsequently. Average feed daily intake, average daily weight gain and feed conversion ratio were calculated accordingly.

**Carcass and organ characteristics:** At the end of the feeding trial, two rabbits per replicate were randomly selected, starved of feed for 24 h, weighed, stunned and bled through the jugular vein. The dressed carcass was weighed and cut parts expressed as a percentage of carcass weight. The cut parts and organ weights were expressed as the percentage of dressed weight. The slaughtered animals were dressed by flaying, eviscerating and splitting. The dressing percentage (DP) was determined as:

$$\text{Dressing (\%)} = \frac{\text{Dressed weight}}{\text{Live weight}} \times 100$$

**Cost benefit evaluation:** The prevailing market prices of the feed ingredients at the time of the experiment were used to estimate the unit cost of the experimental diets. The variable cost of feeding the rabbits 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 kilogram, cost per kilogram of weight gain and cost benefit ratio were also determined (at the time of the experiment, 270 naira (N), Nigeria National Currency was equivalent to One United States Dollar (N280.00 = US$ 1.00).

**Statistical analysis:** Data generated were subjected to analysis of variance and where significant means were found, they were separated using the Duncan's Multiple Range Test[12]. The inclusion related response in production outcomes to MOLM were modeled using the quadratic optimization equation:

$$Y = a+b_1x+b_2x^2$$

Where:

Y = Production variable (feed intake, weight gain, feed conversion ratio, carcass and organ weight)
a = Y intercept
b = Coefficient of quadratic optimization equation
x = MOLM inclusion levels and $-b_1/2b_2$ = x value for optimum response

The quadratic equation was fitted to the experimental data by means of the non-linear model procedure of SPSS[12] and the choice of quadratic function was because it gave the fit.

## RESULTS

**Proximate composition and growth performance:** The proximate compositions of MOLM and experimental diets as shown in Table 2 revealed that MOLM is rich in beneficial nutrients.

The growth performance of grower rabbits fed diets containing MOLM as presented in Table 3 showed that ADWG was significantly ($p<0.05$) influenced by the experimental diets with animals on $T_3$ and $T_4$ diets having the best weights ($p<0.05$) when compared to those on diet $T_1$. The ADFI and FCR were significantly ($p<0.05$) affected by the treatment diets, with the animals on $T_2$, $T_3$ and $T_4$ diets having improved values than the animals on the control diet ($T_1$).

**Carcass and organ characteristics:** Carcass and organ characteristics of grower rabbits fed diets with varying levels of MOLM are presented in Table 4. The slaughter weight, carcass weight and dressing percentage were significantly ($p<0.05$) increased by the treatment diets. Rabbits on $T_2$, $T_3$ and $T_4$ diets had higher ($p<0.05$) slaughter and carcass weights than the rabbits fed $T_1$ diet. Rabbits on $T_3$ and $T_4$ diets had statistically ($p<0.05$) higher dressing percentage than those on $T_1$ and $T_2$ diets. There were treatment ($p<0.05$) effect on hind limb, lion and forelimb, but the weights of thoracic

Table 2: Proximate compositions of the experimental diets and MOLM

| | Dietary MOLM inclusion levels | | | | |
|---|---|---|---|---|---|
| Constituents (%) | $T_1$ (0%) | $T_2$ (10%) | $T_3$ (20%) | $T_4$ (30%) | MOLM |
| Dry matter | 94.05 | 93.98 | 95.06 | 94.79 | 92.19 |
| Crude protein | 19.92 | 19.12 | 18.12 | 18.03 | 29.06 |
| Crude fibre | 14.99 | 15.64 | 16.02 | 16.87 | 17.54 |
| Ash | 10.75 | 10.89 | 11.05 | 10.96 | 12.27 |
| Ether extract | 7.85 | 8.34 | 8.60 | 8.99 | 8.59 |
| NFE | 40.54 | 39.99 | 41.27 | 39.94 | 24.73 |
| Metabolizable energy (kcal $kg^{-1}$) | 2783.35 | 2777.75 | 2809.65 | 2793.10 | 2612.80 |

NFE: Nitrogen free extract

Table 3: Growth performance of grower rabbits fed MOLM based diets

| | Dietary MOLM inclusion levels | | | | |
|---|---|---|---|---|---|
| Parameters | $T_1$ (0%) | $T_2$ (10%) | $T_3$ (20%) | $T_4$ (30%) | SEM |
| Initial body weight (g) | 550.00 | 623.60 | 602.30 | 576.90 | 101.40 |
| Final body weight (g) | 1235.00 | 1434.00 | 1500.00 | 1470.34 | 112.64 |
| Average daily weight gain (g/day) | $16.71^{b}$ | $19.77^{ab}$ | $21.90^{a}$ | $21.79^{a}$ | 1.14 |
| Average daily feed intake (g) | $79.18^{d}$ | $84.84^{c}$ | $87.06^{b}$ | $89.84^{a}$ | 4.74 |
| Feed conversion ratio | $4.74^{a}$ | $4.30^{ab}$ | $4.00^{b}$ | $4.12^{b}$ | 0.78 |

Means in the row with different letters are significant at p<0.05

Table 4: Carcass and organ characteristics of grower rabbits fed MOLM based diets

| | Dietary MOLM inclusion levels | | | | |
|---|---|---|---|---|---|
| Parameters | $T_1$ (0%) | $T_2$ (10%) | $T_3$ (20%) | $T_4$ (30%) | SEM |
| Slaughter weight (g) | $1178.20^{c}$ | $1382.32^{b}$ | $1446.72^{a}$ | $1421.12^{a}$ | 119.15 |
| Carcass weight (g) | $620.74^{c}$ | $744.19^{b}$ | $865.64^{a}$ | $883.43^{a}$ | 67.29 |
| Dressing percentage (%) | $52.69^{b}$ | $53.83^{b}$ | $59.83^{a}$ | $62.16^{a}$ | 3.67 |
| Thoracic cage (%) | 12.08 | 13.10 | 14.96 | 14.61 | 1.78 |
| Hind limb (CW%) | $33.03^{c}$ | $40.21^{b}$ | $44.13^{a}$ | $44.62^{a}$ | 2.39 |
| Loin (CW%) | $19.37^{b}$ | $21.94^{a}$ | $22.37^{a}$ | $21.12^{a}$ | 1.18 |
| Fore limb (CW%) | $15.71^{b}$ | $16.30^{b}$ | $18.37^{a}$ | $17.91^{a}$ | 0.98 |
| Spleen (CW%) | 0.40 | 0.39 | 0.42 | 0.40 | 0.11 |
| Liver (CW%) | $2.52^{c}$ | $2.58^{b}$ | $2.65^{b}$ | $2.89^{a}$ | 0.34 |
| Lung (CW%) | 0.70 | 0.71 | 0.72 | 0.69 | 0.17 |
| Heart (CW%) | 0.57 | 0.40 | 0.48 | 0.46 | 0.13 |
| Kidney (CW%) | $115.00^{b}$ | $1.16^{ab}$ | $1.23^{a}$ | $1.32^{a}$ | 0.26 |

Means in the row with different letters are significant at p<0.05, CW: Carcass weight

Table 5: Economic benefits of grower rabbits fed MOLM based diets

| | Dietary MOLM inclusion levels | | | | |
|---|---|---|---|---|---|
| Parameters | $T_1$ (0%) | $T_2$ (10%) | $T_3$ (20%) | $T_4$ (30%) | SEM |
| Cost /100 kg feed (N) | $2305.00^{a}$ | $2144.00^{b}$ | $1968.00^{c}$ | $1763.00^{d}$ | 19.52 |
| Cost/kg feed (N) | $25.05^{a}$ | $21.44^{b}$ | $19.68^{c}$ | $17.63^{d}$ | 2.01 |
| Total feed consumed (kg) | $3.25^{b}$ | $3.48^{b}$ | $3.57^{a}$ | $3.68^{a}$ | 0.23 |
| TC of feed consumed (N) | $81.41^{b}$ | $74.61^{c}$ | $70.26^{c}$ | $64.88^{a}$ | 8.10 |
| Total weight gain (kg) | $0.69^{c}$ | $0.81^{b}$ | $0.90^{a}$ | $0.89^{a}$ | 0.02 |
| Feed cost/weight gain | $118.00^{a}$ | $92.11^{b}$ | $78.07^{c}$ | $72.98^{d}$ | 8.65 |
| Cost/kg live weight (N) | 500.00 | 500.00 | 500.00 | 500.00 | 0.00 |
| Cost benefit ratio | 1:4.24 | 1:5.43 | 1:6.40 | 1:6.85 | |

Means in the same row with the different letters are significant at p<0.05, TC: Total cost, N: Nigerian Naira

cage, spleen, lungs and heart had comparable (p>0.05) values across the treatments. Liver weight differed (p<0.05) significantly with $T_4$ returning the highest value while $T_1$ having the lowest value.

**Economic evaluation:** The economic evaluation of growing rabbits fed MOLM based rations is presented in Table 5. The cost of production per 100 kg feed differed (p<0.05) significantly within the treatment groups and tended to

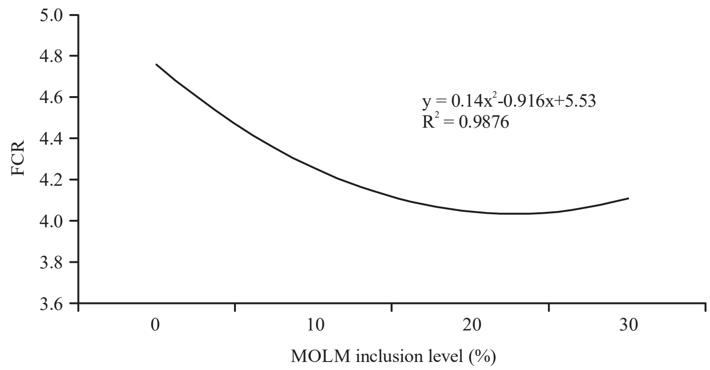


Fig. 1: Curve estimation effect of MOLM on optimum FCR in growing rabbits

Table 6: Dose response effect of MOLM on ADWG, ADFI, FCR and dressing percentage of growing rabbits

| Variables | Formula | $R^2$ | Optimal x-value | Optimal y-value | p-value |
|---|---|---|---|---|---|
| ADWG (g/day) | $y = -0.7925x^2+5.6995x+11.738$ | 0.9951 | 35.96 | 21.99 | 0.033 |
| ADFI (g/day) | $y = -0.72x^2+7.02x+73.08$ | 0.987 | 48.75 | 90.19 | 0.045 |
| FCR | $y = 0.14x^2 - 0.916x+5.53$ | 0.9876 | 32.71 | 4.06 | 0.031 |
| DP | $y = 0.2975x^2+1.9535x+50.012$ | 0.9424 | 32.83 | 69.63 | 0.044 |

$R^2$: Coefficient of determination, x: Optimal x value, y: Optimal y value, ADWG: Average daily weight gain, ADFI, Average daily feed intake, FCR: Feed conversion ratio

decrease with increasing levels of MOLM inclusion in the diets. Cost of production per kilogram of feed also differed ($p<0.05$) among the treatment groups. As the level of inclusion of MOLM in the diets increased from 0% ($T_1$) to 30% ($T_4$), the feed cost/kg for each treatment group decreased. The values for feed cost per weight gain was lowest for the rabbits fed $T_4$ diet (N72.98), however, this unit cost differed ($p<0.05$) significantly from the corresponding unit cost of N118.00 observed in rabbits fed the control diets. Cost benefit ratio showed significant ($p<0.05$) differences with $T_4$ having the best ratio.

**Optimization value:** Dietary MOLM inclusion levels had a quadratic effect on ADWG, ADFI, FCR and dressing percentage in growing rabbits (Table 6, Fig. 1). Dietary MOLM was noticed to have a quadratic effect on optimal ADWG with a quadratic value of 11.738+5.6995 MOLM-0.7925 MOLM$^2$, $R^2 = 0.9951$ with the optimum MOLM inclusion level being 35.96%. Similar quadratic effect was observed in ADFI (73.08+7.02 MOLM-0.72 MOLM$^2$, $R^2 = 0.987$ with the optimum MOLM inclusion level being 48.75%) and FCR (5.53-0.916 MOLM+0.14 MOLM$^2$, $R^2 = 0.9876$ with the optimum MOLM level being 32.71%). Additionally, MOLM was observed to have a quadratic effect on optimal ADWG with a quadratic value fitted to 50.012+1.9535 MOLM+0.2975 MOLM$^2$, $R^2 = 0.9424$ with the optimum MOLM inclusion level being 32.83%.

## DISCUSSION

The dry matter (DM) values of the $T_2$, $T_3$ and $T_4$ diets compared favourably with the $T_1$ diet. The DM content (92.19%) reported for MOLM in this study compared well with 93.63% reported by Aye and Adegun[13] for the same forage. The crude protein (18.03-19.92%) recorded the present study is similar to the value of 19.11-19.25%, reported by El-Badawi *et al.*[14] for growing New Zealand white rabbits fed diets with different supplemental levels of MOLM. The crude protein (CP) values tended to decrease with increasing levels of the test diets. The decrease in the CP content of the experimental is expected since soybean meal (42.80%) which is been substituted for has been reported by Banaszkiewicz[15] to be higher in CP than the value of 29.06% reported for MOLM. The CP content (29.06%) of MOLM reported in this study is in agreement with the value (20-35%) reported by Foidl and Paul[16] for *Moringa oleifera* leaf meal. The crude fiber (CF) contents of the experimental diets increased with increasing levels of MOLM. Furthermore, the crude fibre of the treatment diets (14.99-16.87%) met the CF requirement of 14-18% on DM basis as stated[17] for rabbits. The CF (17.54%) reported for MOLM in the current study is comparable with 15.16 and 16.98%, reported by Jiwuba[9] and Fadiyimu *et al.*[18] for the same plant. However, the observed variations could be due to the processing method, soil type, age at which the leaves were harvested and processed. The ME content of the treatment diets (2777.75-2809.65 Kcal $kg^{-1}$) is in line with the values of 2851.80-2851.95 Kcal $kg^{-1}$ recorded by Njidda and Isidahomen[19] for growing rabbits fed grasshopper meal as a substitute for a fish meal.

The significantly increased ADWG of rabbits on treatment diets over the control diet is in agreement with the report[6] for West African Dwarf goats fed MOLM diets. The result of the present study on ADWG (16.71-21.90 g) recorded in the present study is higher than the value of 7.71-13.25 g reported for growing rabbits fed concentrate to forage ratio[20], but comparable to the values of 15.68-25.36 g for rabbits fed sorghum offal-based diets as reported by Ogundipe *et al.*[21]. The observed significant increase in weight gain of rabbits fed 20 and 30% MOLM relative to those on control diet is in unison with the results of Nuhu[2], who reported improved weight gain in weaner rabbits fed MOLM diets. The significant increase in body weights of the rabbits fed MOLM based diets may be linked to the excellent amino acid value of MOLM[22]. The proteins of *Moringa oleifera* have very high biological values and essential amino acids than that of soybeans[23]. Similarly, Melesse *et al.*[24] reported improved weight in chickens fed MOLM based diets. The increase in ADFI in the current study was in disagreement with the decreasing value reported in rabbits fed sorghum offal-based diets[24] and leaf meals of *Centrosema pubescens* and *Calapogonium mucunoides*[25]. However, this is in agreement with the findings of Bouatene *et al.*[26] for young rabbits fed MOLM. Rabbits on 20% had better followed by those on 30% MOLM.

Carcass weight is a very important parameter of carcass characteristics hence, the higher the carcass weights the higher the degree of meatiness and economic value for the farmer. The dressing percentage ranged between 52.69-62.16% with rabbits on diet T4 (30% MOLM) having the highest value (62.16%) and diet T1 (0% MOLM) returning the lowest value (52.69%). The observed significant increase may be due to the ability of MOLM based diet to support carcass development in growing rabbits. This finding is in agreement with the dressing percentage of 50-56% reported by Fielding[27] in rabbits. The results for cut parts considered (thoracic cage, hind limb, lion and fore limb) favoured the rabbits on MOLM diets when compared to those on the control diet. The increase in the cut parts observed could be attributed to the good balance protein and high biological values of MOLM which translated to increased weight gain. The increase conformed to the earlier study on rabbits fed MOLM as a replacement for soybean meal[28].

It is worthy to note that in a feeding trial, the weight of some internal organs especially liver and kidneys are normally employed to determine the presence of anti-physiological factors in the feed. The increase in internal organ weight beyond the physiological range is used as an index of feed toxicity[29]. The significant ($p<0.05$) increase values of liver and kidney values of the rabbits on the MOLM diets over the control rabbits suggested that the test diets may due to increased physiological and metabolic activity of these in a bid to detoxify some anti-physiological factors contained in MOLM based diets. The comparable spleen, lungs and heart weight suggests that the liver cells were able to detoxify the presence of anti-physiological factors contained in MOLM based rations.

The significant reduction in the cost of feeding with increasing levels of MOLM was in agreement with the results of earlier studies by Ogundipe *et al.*[30], who reported that the need to lower feed cost in order to produce affordable meat and healthy animal products for man cannot be over-emphasized in the face of the dwindling standard of living. The result demonstrated the qualitative benefits and financial returns of using MOLM diets; with $T_4$ having the highest ratio and $T_1$ has the lowest value. This entails an expected benefit of N6.85 for every N1 in cost for $T_4$ diet. This agrees with Adeniji *et al.*[31], who reported that the inclusion of *Moringa oleifera* in the diet of rabbits reduces the cost of feed. This result also suggested that the optimum level of inclusion of MOLM in the diet of rabbits may not have been attained and perhaps incremental level beyond 30% inclusion may still yield higher cost benefit ratio beyond the value recorded for $T_4$ in this trial.

The results of the current experiment reveal that MOLM supplementation had a quadratic effect on ADWG, ADFI, FCR and dressing percentage with a probability values of 0.942 (94.2%) to 0.995 (99.5%) (Table 5, Fig. 1). The coefficient of determination (94.2-99.5%) obtained in the study suggested that there is a high strength of dietary MOLM on ADWG, ADFI, FCR and dressing percentage in growing rabbits using the quadratic function. The ADWG, ADFI, FCR and dressing percentage were seen to be optimized at varying inclusion levels and the basis for the variations could not be ascertained. However, this implies that the disparity in MOLM level for optimizing production traits in the current experiment is a function of production traits in question. Hence, in harmony with the findings of others studies in monogastric on the best dose response values of feed ingredients inclusion rates for optimizing production parameters are usually not static[32,33]. The current results revealed that all production outcome of interest were optimized at a level beyond the inclusion of 30% used in this study. Hence, the further trial of the spectrum of MOLM inclusion level in parametric performance in rabbits is desirable.

## CONCLUSION

From the results, it could be concluded that rabbits fed diets containing *Moringa oleifera* leaf meal recorded the best weight gain, feed intake, conversion ratio, carcass weight, cut parts, organ weight, lower feed cost/kg gain and higher cost benefit. Therefore, *Moringa oleifera* leaf meal could be used as a cheaper protein source to enhance rabbit production without any detrimental effects on performance and carcass characteristics of rabbits. Daily MOLM inclusion rate of 21.99, 90.19 4.06 and 69.63%, respectively are required to optimized average daily weight gain, average daily feed intake, feed conversion ratio and dressing percentage in growing rabbits. Hence, optimizing MOLM inclusion level in the diet of growing rabbits could assist in improving the productivity.

## SIGNIFICANCE STATEMENT

This study revealed that *Moringa oleifera* leaf meal is rich in protein and other beneficial nutrients and may be used to replace soybean meal in rabbit diets. This finding will help animal nutritionists and feed millers reduce the high cost of protein concentrates by replacing soybean meal, the main protein in livestock diet with *Moringa oleifera* leaf meal. The reduced feed cost will translate to the availability of animal products hence assist in closing the food insecurity gap.

## ACKNOWLEDGMENTS

The authors are grateful to the staff of the Department of Animal Production Technology for the approval to carry out the research in the Departmental Teaching and Research farm and also to use their facilities.

## REFERENCES

1. FAO., 1997. The rabbit husbandry, health and production. FAO Animal Production and Health Series No. 21, Food and Agriculture Organization of the United Nations, Rome, Italy.
2. Nuhu, F., 2010. Effect of *Moringa* Leaf Meal (MOLM) on nutrient digestibility, growth, carcass and blood indices of weaner rabbits. M.Sc. Thesis, Faculty of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
3. Jiwuba, P.C., F.O. Ahamefule, I.P. Ogbuewu and K. Ikwunze, 2017. Blood chemistry and haematology of West African dwarf goats fed *Moringa oleifera* Leaf Meal (MOLM) in their diet. Comp. Clin. Pathol., 26: 621-624.
4. Jiwuba, P.C., K. Ikwunze, E. Duada and D.O. Ugwu, 2016. Haematological and serum biochemical Indices of growing rabbits fed diets containing varying levels of *Moringa oleifera* leaf meal. Br. Biotechnol. J., 15: 1-7.
5. Belewu, M.A. and K.O. Ojo-Alokomaro, 2007. Haematological indices of West African Dwarf goat fed leaf meal based diets. Bulg. J. Agric. Sci., 13: 601-606.
6. Jiwuba, P.C., S.O. Okechukwu, M.U. Onyekwere, A.D. Olabode, D.O. Ugwu, I.P. Ogbuewu and F.O. Ahamefule, 2016. Performance of West African Dwarf (WAD) goats fed *Moringa oleifera* leaf meal. Proceedings of the 41st Annual Conference of the Nigerian Society for Animal Production, March 20-24, 2016, Federal University of Agriculture Abeokuta, Nigeria, pp: 711-714.
7. Makkar, H.P.S. and K. Becker, 1996. Nutrional value and antinutritional components of whole and ethanol extracted *Moringa oleifera* leaves. Anim. Feed Sci. Technol., 63: 211-228.
8. Ramachandran, C., K.V. Peter and P.K. Gopalakrishnan, 1980. Drumstick (*Moringa oleifera*): A multipurpose Indian vegetable. Econ. Bot., 34: 276-283.
9. Jiwuba, P.C., 2014. Performance blood profile and apparent nutrient digestibility of West African Dwarf doesfed dietary levels of *Moringa oleifera* leaf meal. M.Sc. Thesis, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.
10. Sanchez, N.R., S. Ledin and I. Ledin, 2006. Biomass production and chemical composition of *Moringa oleifera* under different management regimes in Nicaragua. Agrofor. Syst., 66: 231-242.
11. AOAC., 2000. Official Methods of Analysis. 16th Edn., Association of Official Analytical Chemists, Washington, DC., USA.
12. SPSS Inc., 2007. SPSS Statistical Software. Version 17.0, SPSS Inc., Chicago, IL., USA.
13. Aye, P.A. and M.K. Adegun, 2013. Chemical composition and some functional properties of *Moringa*, *Leucaena* and *Gliricidia* leaf meals. Agric. Biol. J. North Am., 4: 71-77.
14. El-Badawi, A.Y., H.A.A. Omer, A.A. Abedo and M.H.M. Yacout, 2014. Response of growing New Zealand white rabbits to rations supplemented with different levels of *Moringa oleifera* dry leaves. Global Veterinaria, 12: 573-582.
15. Banaszkiewicz, T., 2000. Nutritive value of new rape cultivars stated in the tests for broiler chickens. Ph.D. Thesis, University of Podlasie, Poland.
16. Foidl, N. and R. Paul, 2008. *Moringa oleifera*. In: The Encyclopedia of Fruit and Nutrition, Foidl, N. and R. Paul (Eds.). ABI, Oxfordshire, UK., pp: 509-512.
17. Gidenne, T. and F. Lebas, 2002. Role of dietary fibre in rabbit nutrition and in digestive troubles prevention. Proceedings of the 2nd Rabbit Congress of the Americas, June 19-22, 2002 Habana City, Cuba, pp: 1-13.

18. Fadiyimu, A.A., J.A. Alokan and A.N. Fajemisin, 2010. Digestibility, nitrogen balance and haematological profile of West African Dwarf sheep fed dietary levels of *Moringa oleifera* as supplement to *Panicum maximum*. J. Am. Sci., 6: 634-643.
19. Njidda, A.A. and C.E. Isidahomen, 2010. Haematology, blood chemistry and carcass characteristics of growing rabbits fed grasshopper meal as a substitute for fish meal. Pak. Vet. J., 30: 7-12.
20. Adeyemo, A.A., O.S. Taiwo and O.A. Adeyemi, 2014. Performance and carcass characteristics of growing rabbits fed concentrate to forage ratio. Int. J. Mod. Plant Anim. Sci., 2: 33-41.
21. Ogundipe, S.O., F.O. Abeke, A.A. Sekoni, I.I. Dafwang and I.A. Adeyinka, 2003. Effects of duration of cooking on the utilization of *Lablab purpureus* beans by pullet chicks. Proceedings of the 28th Annual Conference of the Nigerian Society for Animal Production, March 16-20, 2003, Ibadan, Nigeria, pp: 233-235.
22. Chelliah, R., S. Ramakrishnan and U. Antony, 2017. Nutritional quality of *Moringa oleifera* for its bioactivity and antibacterial properties. Int. Food Res. J., 24: 825-833.
23. Zarkadas, C.G., Y.U. Ziran and V.D. Burrows, 1995. Protein quality of three new Canadian-developed naked oat cultivars using amino acid compositional data. J. Agric. Food Chem., 43: 415-421.
24. Melesse, A., W. Tiruneh and T. Negesse, 2011. Effects of feeding *Moringa stenopetala* leaf meal on nutrient intake and growth performance of Rhode Island Red chicks under tropical climate. Trop. Subtrop. Agroecosyst., 14: 485-492.
25. Aderinola, O.A., O.O. Ojebiyi, T.A. Rafiu, J.A. Akinlade and L.O. Adepoju, 2008. Performance evaluation of growing rabbit fed diets containing varying levels of *Centrocema pubescens* or *Calapogonium mucunoides* in the Savanna zone of Nigeria. Proceedings of the 9th World Rabbit Congress, June 10-13, Verona, Italy, pp: 525-528.
26. Djakalia, B., B.L. Guichard and D. Soumaila, 2011. Effect of *Moringa oleifera* on growth performance and health status of young post-weaning rabbits. Res. J. Poult. Sci., 4: 7-13.
27. Fielding, D., 1991. Rabbits. Macmillan Education Ltd., London, UK., ISBN-13: 978-0333523117, Pages: 112.
28. Odetola, O.M., O.O. Adetola, T.I. Ijadunola, O.Y. Adedeji and O.A. Adu, 2012. Utilization of Moringa (*Moringa oleifera*) leaves meal as a replacement for soya bean meal in rabbit's diets. Scholarly J. Agric. Sci., 2: 309-313.
29. Bone, F.J., 1979. Anatomy and Physiology of Farm Animals. 2nd Edn., Reston Publishing Co., Virginia, USA., Pages: 560.
30. Ogunsipe, M.H., J.O. Agbede and O.A. Adedeji, 2014. Performance response, carcass evaluation and economic benefit of rabbits fed sorghum offal-based diets. Afr. J. Food Agric. Nutr. Dev., 14: 8585-8601.
31. Adeniji, A.A., E.S. Gana, I.C. Chibuogwu and C. Onya, 2011. The feeding value of *Moringa oleifera* leaves for growing rabbits. Proceedings of the 36th Annual Conference of the Nigerian Society for Animal Production, March 13-16, 2011, University of Abuja, Nigeria, pp: 610-613.
32. Mbajiorgu, C.A., 2011. The response of male indigenous Venda chickens to diet energy to protein ratios fed from seven up to 13 weeks of age. J. Human Ecol., 35: 161-166.
33. Mbajiorgu, C.A., J.W. Ng'ambi, D. Norris and O.J. Alabi, 2011. Effect of dietary lysine to energy ratio on performance of unsexed indigenous venda chickens. Asian J. Anim. Vet. Adv., 6: 517-524.