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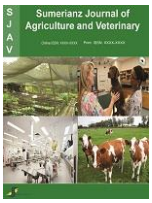

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Growth, Reproduction, Blood Chemistry and Carcass Characteristics of New Zealand White Weaner Rabbit (*Oryctolagus cuniculus*) Fed Different Levels of *Moringa Oleifera* Leaf Meal

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Abstract

The study aimed to evaluate the effects of dietary supplementation with *Moringa oleifera* leaf meal (MOLM) on the growth, reproduction, and biochemical parameters of New Zealand White weaner rabbits. Forty-five (45) female rabbits and ten males, aged eight (8) weeks and weighing between 692 to 695 g, were allocated randomly to five treatments in a Completely Randomized Design (CRD). Treatments included varying levels of MOLM (0 %, 5 %, 10 %, 15 %, and 20 %) in the diets. Data obtained from the experiment were subjected to Least Square Analysis using the GLM type III procedure of SAS. Reproductive performance indices, including litter size at birth, gestation length, and puberty weight, showed no significant differences ($p > 0.05$) among treatment groups. However, feed conversion ratio and days to attain puberty differed significantly ($p = 0.011$) across treatments, with notable impacts on final weight, pre- and post-weaning weights, birth weight, and weaning weight. Moreover, MOLM inclusion influenced milk composition, reducing fat and cholesterol levels, while haematological parameters remained unaffected. Dressing percentage was significantly higher in rabbits fed 5 % MOLM compared to other treatments. Carcass composition and visceral organ weights showed no significant differences among treatments. The study concluded that MOLM supplementation does not adversely affect growth, reproduction, or haematological parameters in rabbits and can potentially reduce cholesterol levels in both blood and milk. However, further investigation is warranted to explore the effects of MOLM inclusion levels beyond 20 % in

rabbit diets. These results depict the potential of MOLM as a beneficial supplement in rabbit diets, impacting nutritional health and enhancing the efficiency of rabbit production systems.

Keywords: Litter size; Moringa; Puberty weight; Pre-weaning weight; Rabbit.

1. Introduction

Animal protein deficiency is a common problem for people in developing countries such as Ghana. Animal protein sources currently consumed in Ghana come from ruminants (sheep, goats, cattle), pig, fish, and poultry, especially chickens [1, 2].

A sixth of all proteins consumed by humans is contributed by poultry and red meat [3, 4] for proper growth and health. The low consumption is due to the high cost of producing highly needed animal protein, making it much more expensive [5, 6]. Rabbits have outstanding high prolificacy, growth rate, shorter generation interval, short gestation period and low fat/cholesterol meat [7, 8].

Rabbit husbandry in Ghana predominantly occurs within rural villages, employing traditional management practices in backyard settings. Recent studies by Maertens [9] echo the conclusions drawn by Ndikumana [10], highlighting the detrimental impact of substandard feed quality on elevated mortality rates and diminished productivity, ultimately resulting in reduced returns on investment. The escalating costs of conventional feed ingredients such as maize, fishmeal, and soybean meal, exacerbated by human and animal consumption competition, intensify the demand for these resources. Consequently, there is a pressing need for cost-effective alternatives in rabbit nutrition. Notably, *Moringa oleifera* leaves emerge as a promising option, given their comprehensive nutritional profile, encompassing essential amino acids, vitamins A, B, C, and a spectrum of minerals, attributes seldom found in plant-derived sources [11, 12]. This study investigated the effects of different levels of *Moringa oleifera* leaf meal on the growth and reproductive performance of New Zealand White weaner rabbits.

2. Materials and Methods

2.1. Study Location

The study was conducted at the Department of Animal Science Farm of the Faculty of Agriculture Education of the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Asante Mampong Campus. Asante Mampong lies between latitude 07˚ 04 N and longitude 01˚ 24 W at 457 meters above sea level and is about 56 km north of Kumasi [13]. Asante Mampong lies in the transitional zone between the high forest and interior savannah, with vegetation characterised by a mixture of tall trees, shrubs, and grasses.

2.2. Experimental Design and Experimental Diet

The experiment employed a completely randomised design with five distinct treatments, where animals were randomly assigned in equal proportions to each experimental diet. Each treatment group consisted of 9 female and 2 male subjects exclusively designated for mating purposes, with three replicates established. Rabbits were individually housed in hutches measuring 50 cm x 50 cm x 30 cm, providing sufficient space for optimal comfort and movement. The five experimental diets were formulated: 0 % *Moringa oleifera* leaf meal (MOLM) as the control, alongside 5 %, 10 %, 15 %, and 20 % MOLM inclusion levels. The Nutrient composition of the experimental diets, including calculated values, is detailed in Table 1.

Table-1. Composition of experimental rabbit diet (kg)

Ingredients	MOLM 0%	MOLM 5 %	MOLM 10 %	MOLM 15 %	MOLM 20 %
MOLM	0.0	5.0	10.0	15.0	20.0
Wheat bran	29.5	26.5	23.0	20.0	17.0
Maize	53.0	53.0	53.0	53.0	53.0
Soybean	15.5	13.5	12.0	10.0	8.0
Salt	0.5	0.5	0.5	0.5	0.5
Premix	0.5	0.5	0.5	0.5	0.5
Dicalcium P	1.00	1.00	1.00	1.00	1.00
Total	**100**	**100**	**100**	**100**	**100**
Calculated Analysis					
Crude protein	16.20	16.17	16.29	16.26	16.23
Crude fibre	4.60	4.90	5.00	5.70	6.00
DE ($Kcalkg^{-1}$)	2782.9	2707.8	2637.9	2562.8	2487.7

2.3. Parameters Measured

2.3.1. Growth, reproductive and fitness performance

The following growth parameters were measured: initial body weight (g), final body weight (g), birth weight (g), weaning weight (g), daily feed intake (g), total feed intake (g), growth rate (g), and feed conversion ratio. Reproductive parameters recorded included pregnancy rate, litter size at birth, and weaning size. Pre-weaning and post-weaning mortality were the sole fitness trait assessments for survival and reproductive performance.

2.3.1.1. Daily feed intake

Daily feed intake, quantified in grams (g/day), was recorded for each animal within the treatment groups. The feed intake was assessed daily and computed as the difference between the amount of feed dispensed and the feed left-over.

2.3.1.2. Feed conversion ratio (FCR)

The feed conversion ratio was calculated by dividing the total feed intake by the body weight gain to determine how efficiently Does convert feed into body weight.

$$\text{Feed conversion ratio (FCR)} = \frac{Total\ feed\ ingested\ (in\ grams)}{Weight\ gain\ (in\ grams)}$$

2.3.1.3. Birth weight and weaning weight

Bunnies born were weighed within 24 hours with a digital scale in grams (g). At the end of 8 weeks, kits were weaned, and respective weights were recorded.

2.3.1.4. Pre-weaning growth rate

The pre-weaning growth rate was expressed as the ratio of total weight gain from birth to weaning to the total number of days in grams per day (g/day).

$$\text{Pre-weaning growth} = \frac{Weaning\ weight - birth\ weight\ (grams)}{Days\ from\ birth\ to\ \text{weaning}}$$

2.3.1.5. Post-weaning growth rate

The post-weaning growth rate was computed as the ratio of total weight gain from weaning to maturity to the total number of days within the period.

$$\text{Post-weaning growth rate} = \frac{Matured\ weight - weaning\ weight\ (grams)}{Days\ from\ weaning\ \text{to}\ maturity}$$

2.3.1.6. Pregnancy rate

Data on pregnancy rate was recorded on the tenth (10^{th}) day after mating and after palpation had been done. These were calculated as:

$$\text{Pregnancy rate} = \frac{Does\ in\ kindle}{Does\ mated} \times 100\ \%$$

2.3.1.7. Litter size at birth and weaning size

Live kits born to each doe were counted and recorded soon after parturition as well as surviving ones up to weaning. These were done within a period of 24 hours.

2.3.1.8. Mortality rate

The mortality rate for pre-weaning and post-weaning were recorded and expressed as:

$$\text{Pre-weaning mortality rate} = \frac{Number\ of\ kits\ died\ \ before\ weaning}{Total\ kits\ hatched} \times 100\ \%$$

$$\text{Post-weaning mortality rate} = \frac{Number\ of\ does\ died\ after\ weaning}{Total\ Nnumber\ of\ weaners} \times 100\ \%$$

2.4. Blood Sample Collection and Analysis

Blood samples were taken from 3 animals per treatment at the end of the experiment and discharged (1 ml) into sterilised universal microlitre tubes with EDTA as an anticoagulant for Haematological analysis. Another 1.0 ml was discharged into labelled sterilised universal microlitre tubes without anticoagulant for biochemical components analysis. The blood samples were collected from each rabbit from the external ear vein using a sterilised disposable syringe and needles in the morning. Before taking the blood, a cotton swab soaked in methylated spirit was used to dilate the veins and to sterilise the area to prevent infection. The blood samples were sent to the haematology Laboratory to analyse total protein, albumin and cholesterol concentration with Auto Analyser (Cell-DYN 1800, Abbott Block Scientific Inc., United States of America). Globulin (Gb) concentration was computed as the difference between Total protein and Albumin concentrations. Red blood cell (RBC), White blood cell (WBC), Haemoglobin and Packed cell volume were analysed with Auto Analyser (Cell-DYN 1800).

2.5. Milk Sample

Three nursing does were selected at random from each treatment. The does were injected with oxytocin at a rate of 1.0 ml for 3 hours, and milking was manually done into sterile tubes.

Milk quality analysis was done at the KNUST Biochemistry Laboratory for total protein, fat, lactose, and cholesterol. Samples of milk were collected at the peak of lactation (at the end of the third week of lactation).

2.6. Carcass Characteristics

At the end of the eight months trial, three does from each treatment were randomly picked and slaughtered for carcass characteristics. The dressed weight and weight of the organs (heart, lungs, liver, spleen, kidneys, stomach,

small and large intestines), visceral fat and tail were recorded using a digital scale balance (F-400 from China). The lengths of small and large intestines were also measured with a tape measure and expressed in cm. Dressing percentage was determined by dividing the dressed weight by the slaughter weight and multiplied by one hundred.

2.7. Statistical Analysis

Data obtained from the experiment were subjected to Least Square Analysis using GLM type III procedure of SAS [14].

$\mathbf{Y_{ij} = \mu + T_i + \varepsilon_{ij}}$

Where:

$\mathbf{Y_{ij}}$ represents the response variable for the j^{th} observation in the i^{th} level of MOLM inclusion.
$\boldsymbol{\mu}$ represents the overall mean.
$\mathbf{T_i}$ represents the effect of the i^{th} treatment levels of MOLM inclusion.
$\boldsymbol{\varepsilon_{ij}}$ represents the residual error term.

3. Results and Discussion

3.1. Proximate analysis of *Moringa oleifera* leaf

Table 2 shows the results of the proximate analysis of the moringa leaf meal (MOLM) used for this study.

Table-2. Proximate composition of *Moringa oleifera* leaf

Description	Value %
Dry matter	88.75
Crude protein	26.95
Crude fibre	14.63
Ether Extract	5.00
Ash	9.00
Nitrogen free extract	33.17

The crude protein (CP) component of 26.95 % in MOLM of this study is similar to 26.70 % reported by Oduro-Owusu, *et al.* [15] but lower than CP values of 27.40 %, 29.25 %, 30.30 % and 40.00 % reported by Owusu, *et al.* [16] [17] Moyo, *et al.* [18] and Sanchez-Machado, *et al.* [19] respectively. The CP values reported by Sarwatt, *et al.* [20] and Nouala, *et al.* [21] were lower than the value recorded in this study. The crude fibre (CF) content value of 14.64 % obtained in this study was lower than 19.10 % and 19.25 % reported by Owusu, *et al.* [16] and Nuhu [17] respectively but higher than 11.10 % reported by Adeniji and Lawal [22]. The ash value of 9 % was higher than 7.13 % 7.98 %, 8.7 %, recorded by Nouala, *et al.* [21]; Ewuola, *et al.* [23] & [22] respectively but lower than 12.00 % reported by Ahmed, *et al.* [24].

The ether extract values of 9.93 % and 6.50 % reported by Ewuola, *et al.* [23] and Moyo, *et al.* [18] respectively were higher than the current results (5 %) but higher than the 2.23 % reported by Nuhu [17]. The NFE and moisture values of 33.17 % and 11.50 % were lower than the 53.5 % and 30 % recorded by Adeniji and Lawal [22]. The differences in the values obtained in this study (CP, CF, EE, NFE and moisture) and others may be due to differences in agro-climatic conditions, age of plant (leaves), processing method and analytical procedures [25].

3.2. Proximate Composition of Experimental Diets

The results of the proximate analysis of the experimental diets are presented on Table 3.

Table-3. Proximate composition of experimental diets

Treatment	MOLM 0 %	MOLM 5 %	MOLM 10%	MOLM 15%	MOLM 20%
Crude protein	16.50	16.20	16.30	16.30	16.34
Crude fibre	5.70	5.88	6.38	6.75	6.91
Ether Extract	1.00	1.10	1.25	1.50	1.52
Ash	5.50	5.41	5.38	5.01	5.52
Moisture	11.20	11.40	12.32	12.91	13.31
NFE	60.1	58.90	58.37	57.53	55.81

The analysed crude protein, ash, and moisture of the diets did not vary much among treatment diets (Table 3). The crude fibre levels increased with increasing moringa levels whilst the ether extract first decreased at 0-10 % moringa inclusion levels and increased again at 10-20 %. It has been reported that soybean contains high amount of lipid [26, 27]; however, the degree of lipid contained in the soybean meal is dependent on the efficiency of the extraction mechanism. The reduction in soybean meal in the diets is believed to be responsible for the reduced ether extract content in the diet. On the contrary, higher MOLM levels (15 % and 20 %) in diets recorded higher ether extract of 1.5 % each than in the control diet (1.0 %). This trend could be attributed to the high ether extract in MOLM (5 %) (Table 2) which consequently increased the corresponding ether extract in the respective diets as inclusion rates increased to 15 % and 20 % MOLM. The levels of crude fibre increased as the inclusion rate of moringa increased from 0 - 20 % because the crude fibre in moringa (14.63 %) was higher than that in soybean (7 %) [28]. A similar trend was corroborated by Rahmawati, *et al.* [29] when soybean meal was substituted with graded levels of MOLM in a feed trial to increase the performance of Javanese thin-tailed ewes.

3.3. Growth Performance of the Does

There were no notable variances ($p > 0.05$) in the initial body weight, pre-puberty and post-puberty feed intake; however, the feed conversion ratio (FCR) and the final body weight exhibited significant ($p < 0.05$) variations (Table 4). Rabbits fed with 5 % or 10 % moringa recorded a relatively higher ($p = 0.011$) FCR compared to the control group. However, rabbits kept on 15-20 % moringa had similar ($p > 0.05$) FCR as does fed 0 %, 5 % and 10 % MOLM. Final body weight showed a trend similar to FCR. The similarities in feed intake observed in the present study may be due to similar energy contents in the diets (Table 1) as rabbits ate to satisfy their energy needs. This trend could be attributed to the fact that feed intake in general depends on energy content of diets [30] when other factors including anti-nutritional factors are held constant. Providing diets with similar energy levels consequently led to similar feed consumption.

Table-4. Growth Performance of the weaner does fed on graded levels of MOLM

Treatment	0 % MOLM	5% MOLM	10% MOLM	15% MOLM	20% MOLM	p-value
IBW(g)	693.44±7.14	692.89±7.14	695.00±7.14	694.56±7.14	692.33±7.14	0.999
PPF(g/d)	69.43±6.21	84.40±6.21	85.77±6.21	79.02±6.21	91.97±6.21	0.1919
POPF(g/d)	268.17±163.8	232.53±176.2	292.68±163.8	260.55±163.8	306.02±163.84	0.6613
FBW (g)	3291.2 ± 126.3^{b}	3694.3 ± 126.2^{a}	3355.2 ± 117.4^{ab}	3374.7 ± 118.2^{ab}	3475.1 ± 113.2^{ab}	0.0326
FCR	6.08 ± 0.01^{c}	5.62 ± 0.06^{d}	7.02 ± 0.06^{a}	6.30 ± 0.06^{b}	7.12 ± 0.06^{a}	0.0001

^{ab}: *Means bearing different superscripts in the same row are significantly different ($p < 0.05$).*
IBW = *Initial body weight*; PPF = *Pre-puberty feed intake;* POPF = *post-puberty feed intake*; FBW = *Final body weight;* FCR = *Feed convent*ion r*atio* .

Does kept on moringa diets, had similar ($p > 0.05$) final body weight (FBW), however, rabbit on 5% MOLM were heavier ($p = 0.033$) than those on the control diet. Dietary protein is directly associated with an increase in body weight such that lack or low levels of amino acids particularly lysine and methionine in the diet depressed growth and weight gain [31]. The heavier weight observed is attributed to some influence of phytochemicals in the moringa leaf which might have promoted gut health for efficient enzymatic feed digestion in the foregut and utilisation [32] before the hindgut fermentation for additional nutrients. Moreover, increased fibre content of diets (Table 3) with moringa could have influenced the extent of fermentation in the caecum for volatile fatty acids and other nutrients which could have contributed to the enhanced final body weight of rabbits fed on the MOLM diets as compared to the control. The result of the body weight obtained is similar to those of El-Desoky, *et al.* [33] where moringa based diets had heavier weight but the highest body weight turned out for rabbits that had the highest inclusion level of the MOLM. Similar result was also deciphered by Abdelsalam and Fathi [34] on a feeding trial using natural feed additives in improving rabbit productivity. Feed conversion ratio (FCR) varied significantly across dietary treatments without an indication of a trend. Rabbits fed on 5 % MOLM had the best efficiency of feed ($p = 0.0001$) as compared to the control which comparatively was also efficient ($p = 0.0001$) than the other dietary treatments and aligns with the findings of Adeyemi [35].

3.4. Growth Performance of kits

Table-5. Effects of MOLM on the growth performance of kits

Parameter	0 % MOLM	5 % MOLM	10 % MOLM	15 % MOLM	20 % MOLM	P- value
BW (g)	52.5 ± 1.6^{a}	45.2 ± 1.5^{b}	50.7 ± 1.4^{a}	46.2 ± 1.4^{b}	44.6 ± 1.4^{b}	0.0003
MFG (days)	9.4±0.18	8.7±0.21	9.3±0.21	9.1±0.21	8.8±0.21	0.0709
MEO (days)	9.6±0.24	9.1±0.27	9.8±0.22	9.9±0.22	9.6±0.22	0.1401
PWG (g)	14.5 ± 0.9^{a}	13.9 ± 1.1^{a}	10.9 ± 1.0^{b}	11.9 ± 1.0^{b}	10.4 ± 1.1^{b}	0.0118
WW (g)	654.7 ± 34.2^{a}	588.4 ± 39.5^{ab}	527.1 ± 38.3^{b}	570.4 ± 36.6^{ab}	488.3 ± 40.1^{b}	0.0118
FI (g/d)	38.8 ± 2.2^{b}	47.7 ± 2.6^{a}	38.8 ± 2.4^{b}	38.3 ± 2.3^{b}	38.5 ± 2.5^{b}	0.0344
POW (g/d)	12.8 ± 2.2^{b}	18.7 ± 1.1^{a}	11.9 ± 1.0^{b}	13.6 ± 1.0^{b}	12.2 ± 1.1^{b}	0.0001
TMW (g)	1216.7 ± 55.48^{b}	1440.7 ± 67.1^{a}	1060.7 ± 62.3^{c}	1047.7 ± 61.5^{c}	1014.4 ± 64.9^{d}	0.0001
FCR	5.22±1.37	1.89±1.36	2.67±1.32	2.42±1.24	2.72±1.17	0.2449

^{abc}: means bearing different superscripts in the same row are significant different ($P<0.05$).
BW = *Birth weight*; MFG = *Mean fur growth*; MEO = *Mean eyes open*; FI = *Feed intake*; PWG = *Pre-weaning growth rate*; WW = *Weaning weight*; POW = *post-weaning growth rate*, TMW = *Three months weight*; FCR = *Feed convention ratio*.

There were significant ($p < 0.05$) differences between the treatment means for most of the growth parameters measured for kits, except days to fur growth, eyes open and FCR. The birth weight of kits on the control diet and the 10 % MOLM diet were similar ($p < 0.01$), and these were significantly ($p < 0.05$) higher than those on the other treatments. Daily feed intake of kits fed on diet that had 5 % MOLM was significantly ($p <0.05$) higher than that of the other treatments which had similar ($p > 0.05$) feed ingestion.

At pre-weaning, kits on the control diet and 5 % MOLM grew faster than those on the 10 %, 15 % and 20 % which had similar ($p > 0.05$) growth rates. Kits fed the control diet had significantly ($p < 0.05$) heavier weaning weights than those fed the 10 % or 20 % MOLM. Kits fed the control diet, 5 % and 15 % MOLM attained similar ($p > 0.05$) weaning weights, and those fed the MOLM diets also had insignificant ($p > 0.05$) weaning weights. At post-weaning, kits on 5 % MOLM grew faster ($p < 0.01$) than kits on all the other treatments. This culminated in the

highest (p = 0.0001) three months weight for kits fed 5 % MOLM than the control and the other MOLM diets which had relatively lower (p < 0.05) weights with increasing MOLM in the diets. FCR for kits on all treatments were similar (p > 0.05) contrary to the observation by El-Desoky, *et al.* [33] who had significant differences among treatments. Although different inclusion levels of MOLM affected milk quality, it did not influence days of growth of furs and eye open. These traits are affected greatly by the genotype more than the environment or feed as noted by Annor, *et al.* [36].

Does fed the control diet (0 % MOLM) recorded better birth weight of kits than those on MOLM diets. High levels of MOLM above 10 % adversely affected the pre-weaning growth of kits. At this stage, kits suckled and as well ate test diets (Table 5). This trend in pre-weaning growth is in consonance with Odeyinka, *et al.* [37]. Kits with similar birth weights should have similar pre-weaning growth rate [35, 38] under similar conditions.

In this study, both weaning pre-weight and post-weaning weight decreased as the MOLM inclusion levels increased. The reduction in weaning weight may be due to high methionine content in the diet as it has a net depressive effect on feed intake and weight gain and also the increased concentration of phytochemicals as inclusion levels increased and inefficiency of hindgut fermentation in the young rabbits [39].

3.5. Reproductive Performance of Does

Table 6 summarizes the major findings on the effect of MOLM on reproductive performance of does.

Table-6. Reproductive performance of rabbit does fed on levels of MOLM

Parameter	0 % MOLM	5 % MOLM	10 % MOLM	15 % MOLM	20 % MOLM	P-value
PW (g)	1838.9±104.5	2045.0±112.4	1963.0±104.5	2047.0±112.4	1881.4±104.5	0.5572
DP	167.67±7.29^{b}	186.20±7.87^{a}	160.00±7.29^{c}	149.95±7.87^{d}	151.56±7.29^{d}	0.0150
MW (g)	2270.9±142.8	2376.7±154.3	2317.7±142.8	2732.2±154.3	2264.9±142.8	0.1845
PR (%)	91.67±7.32	80.67±7.32	100.00±7.32	89.00±7.3	100.00±7.32	0.3597
GD	29.6±0.76	29.6±0.67	30.2±0.68	30.8±0.6	31.6±0.62	0.1397
KW	2213.67±13.58	2065.22±14.3	2188.56±13.6	2359.78±13.6	2025.89±13.6	0.4126
LSB	4.6±0.29	4.9±0.26	4.9±0.27	5.2±0.26	5.4±0.24	0.1545
LSW	3.7±0.28^{a}	2.1±0.26^{b}	2.3±0.26^{b}	3.5±0.25^{a}	1.8±0.24^{c}	0.0001
LW (g)	2205.89±99.6	2284.84±12.1	3192.44±99.6	2332.42±11.1	2264.33±99.6	0.8680
LWL (g)	-4.81±82.80^{b}	220.35±82.80^{a}	3.89±76.99^{b}	-53.81±82.80^{b}	238.44±77.0^{a}	0.0378

^{ab}: Means bearing different superscripts in the same row are significantly different (P<0.05)

NB: PW = *Puberty weight*, DP = *Days to puberty*, MW = *Mating weight*, PR = *Pregnancy rate*, GD = *Gestation days*, KW = *K*indling weight, LSB = *Litter size at birth*, LSW = *Litter size at weaning*, LW = *Lactating weight*, LWL = *Lactating weight loss.*

Similar puberty weight gain, pregnancy rate, gestation days, kindling weight, litter size at birth and lactating weight of different treatments could be ascribed to similar pre-puberty feed intake and post-puberty feed intake (Table 5).

The significant difference observed in days to puberty stage could be attributed to complete amino acid, high profile of vitamins and minerals, antibacterial, antioxidant (pterygospermin), immune stimulants and some growth stimulating compounds found in moringa leaf as these results authenticate similar observations replicated by Khan, *et al.* [40], Adeyemi [35] and El-Kashef [41]. This might have enhanced early days to puberty in does fed MOLM based diet than those on the control diet. High litter size at weaning in the control and 15 % MOLM diets resulted from lower pre- and post-weaning mortality rates in control and pre-weaning mortality rates in does fed 15 % MOLM diet (Table 7). The lactating weight loss recorded in the 0%, 10%, and 15 % MOLM for does could be ascribed to large litter size at weaning as the feed taken by the does was reduced for lactation of kits (Table 6). This outcome was anticipated due to the positive correlation between litter size and milk suckling by kits during the suckling phase, aligning with established nutritional principles.

3.6. Mortality

Mean percentage pre-weaning and post-weaning mortality are presented in Table 7.

Table-7. Effect of M*oringa oleifera* leaf meal (MOLM) on pre-weaning and post-weaning mortality

Parameter	0 % MOLM	5 % MOLM	10 % MOLM	15 % MOLM	20 % MOLM	p- value
Pre-WM %	22.7±2.85^{d}	48.4±4.76^{b}	49.2±4.85^{b}	34.9±34.72^{c}	60.7±4.42^{a}	0.0001
Post-WM %	0.5±1.67^{b}	0.9±1.51^{b}	3.3±1.53^{a}	1.8±1.18^{a}	4.1±1.40^{a}	0.0001

^{ab}: Means bearing different superscripts in the same row are significantly different (P<0.05).

WM =*Weaning mortality*

Pre-weaning mortality increased (p < 0.01) with increasing moringa levels with the animals on the control diet scoring the least mortality rate whilst those on the 20 % MOLM garnered the highest rate. Conversely, post-weaning mortality rates were comparable among animals fed 0 % and 5 % MOLM diets (p > 0.05), as well as among those fed diets containing 10 %, 15 %, and 20 % MOLM. The lowest post-weaning mortality was attained by rabbits fed 0 and 5 % MOLM whilst higher rates were observed in animals fed 10-20 % MOLM.

The elevated levels of methionine present in *Moringa oleifera* leaf meal may lead to methionine toxicity, characterized by the accumulation of free methionine in plasma. This phenomenon, as noted by Bouatene, *et al.* [42] and validated by El-Badawi, *et al.* [43], can trigger significant metabolic disturbances and impair immune function in animals. Given the reported high methionine content in Moringa, animals consuming MOLM-based diets recorded

higher mortality rates during both pre-weaning and post-weaning stages, likely attributable to methionine accumulation in their tissues, ultimately leading to mortality.

3.7. Protein, Fat, Lactose, and Cholesterol Content of Milk

Table-8. Effect of MOLM on milk quality of rabbits

Parameter (%)	0 % MOLM	5 % MOLM	10 % MOLM	15 % MOLM	20 % MOLM	Standard Error	p-value
Protein	7.34[b]	7.17[d]	7.09[d]	7.30[c]	7.38[a]	0.02	<0.0001
Fat	2.46[a]	2.28[b]	2.35[b]	2.42[a]	2.31[b]	0.03	0.0154
Lactose	4.02	4.05	4.02	4.01	4.02	0.013	0.3740
Cholesterol	0.27[a]	0.24[ab]	0.21[bc]	0.18[c]	0.17[c]	0.012	0.0016

[abc]: Means bearing different superscripts in the same row are significantly different (P<0.05).

Percentage protein content of milk decreased ($p < 0.01$) at 0 % MOLM inclusion level to 10 % and increased ($p < 0.001$) thereon at 20 % inclusion level. The best milk protein was produced by does fed on the highest (20 %) MOLM (Table 8).

Fat levels of milk reduced ($p < 0.05$) with increasing moringa levels inclusion. The percentage of fat in the milk of does fed the control diet and 15 % MOLM were similar ($p > 0.05$) and differed from the does fed 5%, 10%, and 20 % MOLM which were also similar ($p > 0.05$) with no particular trend. The percentage of lactose in the milk of does of the various treatment diets were similar ($p > 0.05$). Milk cholesterol levels decreased significantly ($p < 0.01$) with increasing moringa levels, with the lowest cholesterol levels observed in does fed 10 – 20 % MOLM diets.

The high percentage of protein in the milk of the 20 % MOLM fed animals may be attributed to its high digestible total soluble protein which makes MOLM more suitable to monogastric animals [44, 45]. Higher levels of MOLM could also strengthen the hindgut microbial fermentation which might yield increased microbial protein that might be utilised through caecotrophy [46].

This study showed that, increasing MOLM in diets of rabbits led to corresponding decrease in cholesterol levels in milk. MOLM therefore has the potential to reduce cholesterol level in milk of rabbits [47] due to anti-cholesterol properties in the moringa leaf although plants are generally low in cholesterol concentration. This can tend to growth depression effect on kits as milk cholesterol is an essential factor for growth due to the role it plays in bone development and growth through metabolic reaction in the formation of vitamin D [48] which is essential for calcium absorption. However, the relatively low cholesterol level of the milk did not impact negatively in this study as weight of kits were higher than the control that had higher milk cholesterol. Perhaps, the impact could have been observed in the bone breaking strength but this was not studied in this experiment. The fat content in milk was lower in all the rabbits fed the MOLM diets which may be as a result of anti-fat activity by the phytochemicals in *Moringa oleifera* leaves. The consistent lactose content observed in this study indicates that incorporating MOLM into diets at levels of up to 20 % did not elicit any discernible impact on lactose synthesis in milk**.**

3.8. Blood Profile of Rabbits

The haematological and biochemical data of doe rabbits fed on MOLM are shown in Tables 9 and 10 respectively.

3.8.1. Haematological components of weaner rabbits fed on MOLM

Table-9. Haematological components of weaner rabbits fed on MOLM

Parameter	0 % MOLM	5 % MOLM	10 % MOLM	15 % MOLM	20 % MOLM	Standard Error	p-value
PCV (%)	36.87	39.40	43.00	40.20	41.80	2.58	0.7603
WBC (10^6/µl)	6.2	6.4	6.5	5.9	5.1	0.60	0.5272
RBC (10µl)	4.7	4.0	4.0	4.9	4.2	0.22	0.1029
Haemoglobin(g/dl)	8.4	8.2	8.6	8.8	9.2	1.44	0.6348
Neutrophil %	36.3	40.4	35.8	38.7	37.1	0.18	0.5399
Eosinophil %	1.8	1.9	2.5	2.3	2.0	0.38	0.4982
Lymphocytes %	26.0	27.7	28.3	27.3	30.0	5.79	0.9911

No significant differences ($p < 0.05$) were observed in all the haematological parameters measured. Values recorded were within the normal physiological ranges (Table 9) for rabbits (31.0 – 51.0, 5.0 – 8.0, 3.0 – 12.5, and 8.0 – 17.0) respectively, for PCV, RBC, WBC and haemoglobin as reported by Annon [49]. Dietary treatments fed to the rabbits were balanced to support their normal growth and reproduction to maintain the normal biochemical profile. When the haematological values fall within the normal range reported for rabbits, it is an indication that the diets did not show any adverse effects on haematological parameters during the experimental period. Still, when the values fall below the normal range, it is an indication of anaemia [50].

The different levels of MOLM in the diet had little effect on the haematological indices of the animals. The trend in this study (haematological indices) shows no differences in the quality, quantity and anti-nutritional factors in the rabbits' feed. The normal white blood cell (WBC) reported was an indication of absence of microbial infection

or antigen in the circulatory system. Dietary supplementation of MOLM may increase the immune ability of animals as a result of the presence of phytochemicals Maqsood, *et al.* [51] and Safwat, *et al*. [52].

The diminished haemoglobin (Hb) levels observed among animals subjected to the treatment diets may suggest inadequate dietary protein provision. However, as the inclusion levels of MOLM increased, so did the haemoglobin concentrations. These haematological findings from this study signify that the dietary formulations were nutritionally adequate to meet the physiological requirements of the rabbits for haematopoiesis [53]. Apart from genotype, age, and sex, differences in haematological indices may be caused by nutritional factors [54]. Changes in haematological parameters are often used to determine stress due to nutrition and other factors [55].

3.8.2. Biochemical components of weaner rabbits fed on MOLM

The effect of MOLM on carcass parameters are presented in Table 11.

Table-10. Effect of MOLM on Biochemical components

Parameter	0 % MOLM	5 % MOLM	10 % MOLM	15 % MOLM	20 % MOLM	Standard Error	P-value
Total serum protein g/dl	7.10[a]	6.33[b]	6.30[b]	6.67[b]	6.17[b]	0.19	0.0435
Globulin g/dl	3.20	2.80	2.70	2.30	2.40	0.23	0.154
Albumin g/dl	3.90	3.60	3.50	3.80	3.70	0.14	0.378
Cholesterol mg/dl	43.67[a]	40.67[ab]	40.17[ab]	38.50[b]	37.30[b]	1.25	0.050

[ab]: Means bearing different superscripts in the same row are significantly different (P<0.05).

There were no observable differences in the concentration of globulin and albumin in the blood of rabbits on all the dietary treatments (Table 9). A reduction in overall serum protein concentration was noted in animals fed MOLM in contrast to those receiving the control diet. A significant decrease in blood cholesterol levels was observed with the increased inclusion of moringa in the diet regimen (p = 0.05) (Table 9). Pesti [56] Observed that two feeds may have the same CP quantity but different biological values. Onu and Aniebo [57] asserted that the total serum protein decreased with increasing levels of MOLM inclusion in feed. This could be due to declining levels of soybean meal (higher biological protein) and increasing levels of MOLM (lower biological value).

The present study recorded a negative relationship in blood cholesterol levels. An increase in moringa levels resulted in a decrease in cholesterol levels in the blood. The study agrees with the report by Xu, *et al.* [58] that moringa has hypocholesterolemic properties in its leaf.

3.9. Effect of MOLM on Carcass Characteristics

The effect of MOLM on carcass parameters are presented in Table 11.

Table-11. Effect of MOLM on wet visceral organs, visceral fat and tail as percent live weight

Parameter	0 % MOLM	5 % MOLM	10 % MOLM	15 % MOLM	20 % MOLM	Standard Error	p-value
Live weight (g)	2105.67	2188.00	2332.33	2471.33	2228.33	195.59	0.7234
Carcass with furs (g)	2053.00	2138.67	2280.67	2411.00	2138.00	190.88	0.7049
Carcass without furs (g)	1701.33	2067.67	1959.67	2081.67	1791.67	188.88	0.5583
Dressed weight (g)	1272.33	1628.67	1503.33	1601.67	1610.67	142.98	0.4280
Dressing percentage (%)	63.38[b]	74.15[a]	66.11[b]	66.58[b]	72.20[a]	1.422	0.002

[ab]: Means bearing different superscripts in the same row are significantly different (P<0.05).

Treatment effects on live weight, weight of carcass with fur, weight of carcass without fur and dressed weight were not significantly (p > 0.050) different. Treatment effect on dressing percentage was significant (p < 0.05). Animals across all dietary inclusion levels had similar (p > 0.05) dressing percentage except for those fed on 5 % and 20 % MOLM which had the higher (p = 0.002) dressing percentage (74.15 % and 72.20 % respectively) as compared to the other dietary treatments (Table 11). Results on dressing percentage corroborate that of El-Desoky, *et al.* [33] although values obtained were relatively low than those in this study.

Except the dressing percentage, this study authenticates the findings of Nuhu [17] who reported no significant differences on slaughter weights; hot carcass weight, carcass weight, dressed weight, full gastro-intestinal tract (GIT), empty GIT, heart, lungs, and empty caecum of rabbit fed MOLM. Animals fed on 5 % MOLM had the highest dressed weight (Table 11). This could be ascribed to their good FCR (Table 4).

3.9.1. Effect of MOLM on Wet Proportion of Heart, Lungs, Kidneys, Liver, Spleen, Visceral Fat and Tail to Body Weight

Treatment effects on heart, lungs, kidneys, liver, spleen, visceral fat and tail were insignificant (p > 0.05). The weights of these organs were similar for all the dietary treatments (Table 12).

Table-12. Effect of MOLM on wet visceral organs, visceral fat and tail as percent live weight

Parameters	0% MOLM	5% MOLM	10% MOLM	15% MOLM	20% MOLM	Standard Error	P-Value
Heart %	0.25	0.29	0.28	0.56	0.30	0.03	0.7588
Lungs %	0.85	0.54	0.71	0.72	0.65	0.08	0.2178
Kidneys %	0.59	0.54	0.55	0.60	0.62	0.06	0.7292
Liver %	3.85	3.38	5.36	4.50	3.87	0.56	0.2065
Spleen %	2.46	2.23	2.87	2.29	2.53	0.73	0.0607
Visceral fat %	7.50	11.30	7.60	12.80	8.07	3.73	0.7860
Tail %	2.80	2.25	2.14	2.13	2.39	1.09	0.0550

[ab]: Means bearing different superscripts in the same row are significantly different (P<0.05).

Dietary treatment effects on the spleen, liver, heart, lungs visceral fat, kidney weights expressed as percentage of the live weight (LW) of the rabbits fed dietary levels of MOLM were similar. The results obtained indicate that inclusion of MOLM in rabbit diets up to 20 % had no adverse effect on these organs, and thus could be used as an alternative feed ingredient in rabbit diets and corroborates earlier observation by Nuhu [17]. The tail weight increased with increasing moringa levels as observed for body weight gain.

4. Conclusion

Based on the finding, it is evident that the inclusion of MOLM at a 5 % level significantly enhances the growth performance of weaner rabbits. MOLM demonstrates potential in reducing the duration required to reach puberty and mitigating lactation weight loss in nursing does. MOLM has no detrimental effects on the haematological and biochemical components of rabbits and has the potential to reduce cholesterol level in the milk and blood of rabbits. Moringa leaf meal could be used to improve dressing percentage of rabbits at 5 % inclusion level. For optimal growth performance, it is recommended to integrate MOLM into the diet of weaner rabbits at a 5 % inclusion level. However, for reproductive benefits, a higher inclusion level of 20 % is recommended.

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