MINERAL COMPOSITION OF MORINGA OLEIFERA LEAF MEAL (MOLM) AND THE RESPONSES OF ROSS 308 BROILERS TO MOLM SUPPLEMENTATION

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Abstract. A 42-day study was designed to determine the mineral composition of *Moringa oleifera* leaf meal (MOLM) and the response of Ross 308 broilers to dietary MOLM supplementation. Day-old Ross 308 broiler chicks (n = 500) were allotted to five treatments in completely randomized design with each group replicated five times with each replicate having 20 chicks. Birds received diets supplemented with MOLM at 0, 25, 50, 75 and 100 g/kg feed, respectively and assigned T1, T2, T3, T4 and T5. MOLM level that supported optimum variables was modelled using the quadratic function. At day 42, three birds per replicate were slaughtered to evaluate carcass and organ yields. Results of mineral assay indicate that MOLM was high in calcium, sodium, potassium, sulphur and iron. Daily feed intake (FI), average daily gain (ADG) and feed conversion ratio were the same among the groups with the exception of starter broilers on diet T1 that had higher ADG ($p < 0.05$) than those on the other diets. Final live weight (FLW), mortality and gizzard weight were influenced ($p < 0.05$) by MOLM supplementation. MOLM supplementation had no effect on other parameters measured. MOLM supplementation at 39.98 and 35.80 g/kg feed supported optimum FLW and ADG at starter phase and 46.88 g/kg feed MOLM supported optimum FLW at finisher phase. In conclusion, MOLM is a good source of nutrients and suitable for production of enhanced cut parts in broiler chickens.
Keyword: *alternative feedstuffs, broilers, optimization, production outputs, South Africa*

Introduction

The development of the broiler industry as a means of bridging the food and nutrition insecurity gap in most countries has been attracting great attention (Dieye et al., 2010). Unfortunately, the growth of the broiler sector in most developing countries are constrained by the spiralling feed cost due to rising prices of feed ingredients particularly protein supplements (Abbas, 2013). This spiralling feed cost is having negative impacts on the feed supply chain as well as the quality of the compounded rations. This rising price of feeds has been partly attributed to the competition between humans and animals for protein and energy concentrates. Therefore, it has become imperative that the potential of alternative protein feedstuffs that are not in direct competition with humans be fully harnessed in broiler nutrition (Ogbuewu et al., 2015, 2019). One of the best-suited alternative plant protein feed raw material for broiler feeding in the developing countries is the leaf of Moringa plant.

Moringa oleifera belongs to the family Moringaceae and thrives well during severe drought and heat. *Moringa oleifera* is one of commonest specie among the 14 species in the family and grows to a height of 7–12 m. It is native to India, but thrive well in the tropics (Nsofor et al., 2012). The leaves of moringa plant are high in essential amino acids, protein, minerals, vitamin A and fibre (Ustundag and Ozdogan, 2015) and could

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be incorporated in broiler feed. In addition, *M. oleifera* leaf meal contains 2.4% ether extract, 25.4% crude protein, 17.4% crude fibre and 5.9% ash (Alnidawi et al., 2016) as against 18.8% ether extract, 42.8% crude protein, 20% crude fibre and 5.5% ash in (Banaszkiewicz, 2000). *Moringa oleifera* leaf therefore is lower in protein than soybean but much higher in ash (minerals) value thus supporting the earlier reports of Ustundag and Ozdogan (2015) that *M. oleifera* leaf can partially substitute soybean and fishmeal in broiler rations without negative impacts of production data while lessening the prize of feed (Ebenebe et al., 2012). In addition, research has established that *M. oleifera* leaves are abundant in water and fat-soluble vitamins as well as lutein and β-carotene (Igwilo et al., 2014; Saini et al., 2014). Evidence also exists that *M. oleifera* leaf is a storehouse for a variety of essential bioactive elements such as saponins, flavonoids, and phenols among others (Saini et al., 2016).

Feeding trial conducted by Kakengi et al. (2007) in chickens fed *M. oleifera* leaf meal revealed enhanced feed and dry matter intake hence showing the palatability of the *M. oleifera* leaf meal based diets to the chickens. In view of this observation, other authors (Onu and Aniebo, 2011; Onunkwo and George, 2015) fed broilers diet containing 10% MOLM and noticed to boost feed utilization and weight gain in comparison with birds fed 0% MOLM. In experiment conducted in native chickens, Gadzirayi et al. (2012) observed reduced feed consumption and enhanced growth rate in birds that received MOLM at 5% as a substitute for soybean meal (SBM) when compared with the group fed SBM alone as the main protein source. Increased egg production and egg mass in laying hens fed 20% MOLM has been documented (Kakengi et al., 2007). Also, improved growth rate and blood constituents in goats and fish fed MOLM have been reported (Paul et al., 2013; Jiwuba et al., 2017).

Several publications have been documented on the use of Moringa leaves as a feed resource for livestock and poultry (Gadzirayi et al., 2012; Paul et al., 2013; Onunkwo and George, 2015; Jiwuba et al., 2017). However, there is no comprehensive data on the mineral assay of moringa leaves and such knowledge will allow farmers to optimize the nutritional value of this plant in animal production. Hence, it has become important to investigate the mineral constituents of leaf meal of *Moringa oleifera* plant and their influence on the production characteristics of meat typed chickens. The objectives of this feeding trial therefore, was to determine the mineral content of *M. oleifera* leaf meal and the effect of its supplementation on production physiology of Ross 308 broilers. The *M. oleifera* leaf meal supplementation level that supported optimum performance in Ross 308 broilers were also reported.

Materials and methods

Study site and preparation of Moringa oleifera leaf meal

The study was performed in a private broiler farm located at Plot 519 Zuurbekom, Gauteng province, South Africa in the months of December 2017 to January 2018. Gauteng province is located at the Highveld of South Africa and lies between latitude 26° 11’ 42.8856” S and longitude 28° 2’ 2.716” E. Fresh and tender leaves of *M. oleifera* were harvested in Grootfontein, a village near Polokwane in Limpopo province of South Africa and air-dried for 3-5 days to a moisture level of about 10%. Thereafter, the dried leaves were milled and stored in unused feedbags for determination of mineral content and diet formulation.

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Mineral analysis

The mineral values were determined in triplicates in the Department of Animal Science Laboratory, North-West University-Mafikeng Campus, South Africa as described by AOAC (2000). The mineral constituents determined were calcium (Ca), phosphorus (P), potassium (K), magnesium (Mg), sodium (Na), sulphur (S), iron (Fe), chromium (Cr) and manganese (Mn).

Experimental procedures

Day-old Ross 308 broiler chicks (n = 500) were allotted to five treatments in completely randomized design with five replications with each replicate having 20 chicks. Birds received commercial mash diets (*Table 1*) supplemented with MOLM at 0, 25, 50, 75 and 100 g/kg feed, respectively and tagged T1, T2, T3, T4 and T5. Birds were procured from the National Chicks' Hatcheries located in the Boschkop area of East of Pretoria, Gauteng province, South Africa. The floor of each pen was swept, scrubbed with a strong brush, thereafter cleaned with water and later disinfected with Virkon® S. Pens were left open for several days after cleaning with Virkon® S as to break the breeding cycle of the pathogens that may have escaped the actions of the disinfectant. The floor of each of the pen was covered to a depth of 7 cm with fresh sawdust under a deep litter management system. The drinkers, feeders, and accessories were assembled and carefully positioned 7 days before the chicks arrived. In addition, pens were heated for 24 h via an infrared light before the chicks arrived. The starter diet (21.0% crude protein) and grower diet (19.0% crude protein) were formulated according to NRC (1994) standard to meet the nutrient requirements of the experimental birds. Feed and water were offered ad libitum and the investigation lasted for 42 days. All the biosecurity measures conformed to the rules and guidelines of the Ethics Committee of the University of South Africa and the South African Animal Disease Act 35, of 1984.

Table 1. *Nutrient content of the diets used in the experiment*

Nutrient* (%)	Starter (0-21 days)	Grower (22–42 days)
Crude protein	21.0	19.0
Lysine	1.30	1.15
Methionine	0.58	0.5
Moisture	12.0	12.0
Fat	2.5	2.5
Fibre	5.0	6.0
Calcium	1.2	1.2
Phosphorus	0.6	0.55

*As illustrated in feed label

Data collection

The initial live weights (LWs) of broiler chicks in each pen were taken at the beginning of the study and weekly thereafter to obtain the weekly LW and weight difference. The mean LW of birds on each pen was determined by dividing total LW by the number of birds in the pen. Feed consumption was determined by subtracting the leftover feed in the feeding trough the following morning from the quantities of feed

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offered daily to the birds. Average daily gain in each pen was computed as the quotients of the LW at the end of the study less the live weights at the start of the study and the period the investigation lasted. Feed conversion ratio (FCR) was determined as the quotient of FI and ADG. At 42 days, 15 birds were chosen from each treatment, denied of feed for 12 h and thereafter, slaughtered to assess the carcass and organ weights. The carcass, organ and cut parts were weighed and expressed as a percentage of the live weight and carcass weight respectively following the procedures of Chukwukaelo et al. (2018).

Data analysis

Data collected were subjected to one-way analysis of variance (ANOVA), and differences in means where significant F-test ($p < 0.05$), Duncan's multiple range test (Duncan, 1955) method was used to separate the means (SPSS 24.0 package). The supplementation related responses in growth and production parameters to MOLM in Ross 308 broilers were modeled using the following quadratic optimization equation:

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

where Y = growth indices (LW, FI, ADG, FCR and mortality), carcass, dressing percent, cut parts (breast, thigh and drumstick) or organ (liver, heart and gizzard) weight; a = the Y intercept; b = coefficient of quadratic optimization equation; x = MOLM supplementation levels and $-b_1 / 2b_2 = x$ value for optimum response. The quadratic equation was fitted to the experimental data by means of the nonlinear model procedure of SPSS 24.0. The choice of the quadratic regression model is because it fitted the model and the probability level for significance is 5%.

Results

Nutrient composition of experimental diet and MOLM

The results of the nutrient content of the treatment diets are shown in *Table 1*. The crude protein levels were 21.0% for the starter mash and 19.0% for the grower mash. *Table 2* presents the mineral composition of MOLM. The mineral content of the MOLM contains appreciable levels of beneficial minerals, including calcium, phosphorus, magnesium, sodium, potassium, iron, sulphur, chromium and manganese showing that MOLM is a source of mineral for livestock. The coefficient of variation (CV) values across sample measurements for the minerals were higher and ranged from 61.35–81.70%.

Growth performance of starter broilers

Table 3 presents the growth indices of starter Ross 308 broilers fed with diets supplemented with varying levels of MOLM. Broilers fed diet T1 recorded the highest FLW of 833 g, which was significantly different from birds on diets supplemented with MOLM at 25, 50, 75 and 100 g/kg feed. ILW and DFI had similar ($p > 0.05$) value in the groups. ADG decreased ($p < 0.05$) steadily with increasing supplementation levels of MOLM. Birds on diet T1 (0 g MOLM/kg feed) had better FCR when compared with birds that received diets supplemented with MOLM at 25, 50, 75 and 100 g/kg feed,

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however, the difference was not significant ($p > 0.05$). Mortality rate was significantly ($p < 0.05$) higher for birds on diet T1 when compared with birds fed the other four diets.

Table 2. *Macro and micro mineral composition of MOLM (mg/kg)*

Parameters	Mean ± SD	CV (%)
Calcium	2687.41 ± 188.68	70.20
Phosphorus	120.73 ± 8.68	71.85
Magnesium	250.00 ± 17.88	71.51
Sodium	968.02 ± 6.03	62.32
Potassium	734.59 ± 45.10	61.35
Iron	316.98 ± 31.68	73.73
Sulphur	1144.09 ± 87.52	76.44
Chromium	3.21 ± 0.26	81.7
Manganese	12.52 ± 0.14	67.18

SD – Standard deviation; CV – Coefficient of variations

Table 3. *Growth indices of starter broilers (1-3 weeks) fed MOLM supplemented diets*

MOLM Level	ILW (g)	FLW (g)	DFI (g)	ADG (g)	FCR	Mortality (%)
0 g/kg feed	40.73	833.87[a]	34.59	37.77[a]	2.29	3.00[a]
25 g/kg feed	39.64	771.56[b]	32.46	34.85[b]	2.40	0.00[c]
50 g/kg feed	40.10	770.49[b]	32.80	34.78[b]	2.40	0.00[c]
75 g/kg feed	40.03	748.72[b]	32.86	33.75[b]	2.43	1.00[b]
100 g/kg feed	39.39	728.30[b]	31.19	32.81[b]	2.41	0.00[c]
Mean	39.98	770.59	32.78	34.79	2.39	0.80
SD	0.51	39.60	1.22	1.86	0.06	1.30
CV (%)	1.28	5.13	3.70	5.35	3.96	-
SEM	0.23	17.71	0.54	0.83	0.03	0.58
p-value	0.06	0.01	0.06	0.02	0.14	0.02

Means with the same letters within column differed statistically at $p < 0.05$, ILW – initial live weight, FLW – final live weight, DFI – daily feed intake, ADG – average daily gain, FCR – feed conversion ratio, SD – standard deviation, CV – coefficient of variation, SEM – standard error of the mean

Growth performance of finisher broilers

The result of growth indices of finisher Ross 308 broilers fed with diets supplemented with varying levels of MOLM as shown in *Table 4*. Higher FLW ($p > 0.05$) was reported control birds fed MOLM at 0 g/kg feed than those fed diets supplemented with MOLM at 25, 50, 75 and 100 g/kg feed. Broilers fed MOLM supplemented diet at 0, 25, 50 and 100 g/kg feed had comparable ($p > 0.05$) ILW, DFI, and ADG values. Birds fed MOLM supplemented diet at 75 g/kg feed had the best FCR, although the difference was not significant ($p > 0.05$) compared with the groups fed the other four diets. Birds on 0 g/kg feed MOLM had the highest mortality ($p < 0.05$) when compared to the birds supplemented with 25, 50, 75 and 100 g/kg feed MOLM.

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Table 4. *Growth indices of finisher broilers (4–6 weeks) fed MOLM supplemented diets*

MOLM Level	ILW (g)	FLW (g)	DFI (g)	ADG (g)	FCR	Mortality (%)
0 g/kg feed	763.87	3000.40[a]	124.57	74.76	1.54	5.00[a]
25 g/kg feed	761.56	2848.40[b]	122.69	69.70	1.40	0.00[b]
50 g/kg feed	760.49	2761.20[b]	122.16	69.65	1.63	0.00[b]
75 g/kg feed	768.72	2729.33[b]	123.38	69.36	1.31	2.00[b]
100 g/kg feed	768.30	2699.26[b]	121.90	70.17	1.41	0.00
Mean	764.59	2807.72	122.94	70.73	1.46	1.40
SD	4.60	121.30	1.07	2.27	0.13	2.19
CV (%)	5.13	4.32	0.87	3.21	8.66	156.48
SEM	5.71	55.25	0.48	1.02	0.06	0.98
p-value	0.610	0.038	0.75	0.82	1.14	0.02

Means with the same letters within column differed statistically at $p < 0.05$, ILW – initial live weight, FLW – final live weight, DFI – daily feed intake, ADG – average daily gain, FCR – feed conversion ratio, SD – standard deviation, CV – coefficient of variation, SEM – standard error of the mean

Relative carcass and organ weight of finisher broilers

The performance in terms of the relative weights of the carcass and organs are presented in *Table 5.* Birds fed diet with MOLM at 0 g/kg feed had higher live weight ($p < 0.05$) than those on diets supplemented with MOLM at 25, 50, 75 and 100 g/kg feed. Birds on diet with MOLM at 0 g/kg feed had higher non-significant ($p > 0.05$) carcass weight than those on diets with MOLM at 25, 50, 75 and 100 g/kg feed. Although, broilers on diets with MOLM at 75 g/kg feed returned the highest non-significant dressing percent ($p > 0.05$) relative to the birds on the other four diets. Cut parts and organ weights of broilers fed MOLM supplemented diets at 25, 50, 75 and 100 g/kg feed had the same values.

Table 5. *Relative carcass and organ weight values of finisher broilers fed MOLM supplemented diets*

Parameters	MOLM inclusion (g/kg feed)					Mean	SD	CV	SEM	P-value
	0	25	50	75	100					
LW (g)	3000.40[a]	2848.40[b]	2761.20[b]	2729.33[b]	2699.26[b]	2807.72	121.30	4.32	55.25	0.0384
CW (g)	2911.53	2778.93	2690.53	2659.60	2637.86	2735.69	112.01	4.09	50.09	0.1128
BW (%CW)	27.26	25.54	30.02	25.27	27.42	27.10	1.90	7.00	0.85	0.3960
DW (%CW)	16.81	17.11	18.02	18.65	18.64	17.85	0.85	4.78	0.38	0.5208
TW (%CW)	21.23	22.83	22.90	23.73	23.66	22.87	1.01	4.49	0.45	0.6315
HW (%LW)	3.01	1.94	2.28	2.08	2.04	2.27	0.43	19.01	0.19	0.0828
LW (%LW)	9.26	9.76	10.13	10.46	10.54	10.03	0.53	5.27	0.24	0.9785
GW (%LW)	7.87[b]	9.19[a]	8.56[ab]	8.56[ab]	10.21[a]	8.88	0.88	9.89	0.39	0.2358
DP (%)	97.04	97.56	97.42	97.45	97.71	97.44	0.25	0.25	0.11	0.0781

Means in the same row sharing the same superscript are significant ($p < 0.05$). LW – live weight, CW – carcass weight, BW- breast weight, DW – drumstick weight, TW – thigh weight, HW – heart weight, LW – liver weight, GW – gizzard weight, DP – dressing percent, SD – standard deviation, CV – coefficient of variation, SEM – standard error of the mean

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Optimization functions

The results of the effect MOLM supplementation on FLW and ADG in Ross 308 broilers are presented in *Tables 6* and *7*. FLW and ADG were optimized at 2538.4 – 173.97 MOLM + 21.756 $MOLM^2$, $r^2 = 0.8994$ and 79.334 – 5.8806 MOLM + 0.8214 $MOLM^2$, $r^2 = 0.8960$ respectively in starter broilers while FLW was optimized at 3173.7 – 200.36 MOLM + 21.371 $MOLM^2$, $r^2 = 0.9928$ in finisher broilers.

Table 6. *Quadratic analysis of the effect of MOLM on FLW and ADG in starter broilers*

Variables	Formula	r^2	x-value	y-value	P-value
FLW	$Y = 2538.4 – 173.97x + 21.756x^2$	0.8994	39.98	2190.63	0.0100
ADG	$Y = 79.334 – 5.8806x + 0.8214x^2$	0.8960	35.80	68.81	0.0200

Table 7. *Quadratic analysis of the effect of MOLM on FLW in finisher broilers*

Variable	Formula	r^2	x-value	y-value	P-value
FLW	$Y = 3173.7 – 200.36x + 21.371x^2$	0.9928	46.88	2704.09	0.0384

Discussion

The objective of this feeding investigation was to determine the responses of Ross 308 broilers to commercial diets (starter and grower) mash supplemented with varying levels of MOLM. The starter diet contained crude protein level of 21.0% while grower contained crude protein level of 19.0% with similar levels of other essential nutrients that satisfied the bird’s nutrient demands as endorsed by NRC (1994) for poultry.

Minerals are vital in poultry nutrition because they serve as cofactors for several biological processes. Calcium, an important mineral for bone growth, muscle, and neurological functions are high in MOLM with the order of macro mineral level being calcium (2687.41 mg/kg) > sodium (968.02 mg/kg) > potassium (734.59 mg/kg) > magnesium (250.00 mg/kg) > phosphorus (120.73 mg/kg) as determined in the current study. These observations are in harmony to the value recorded by Sena et al. (1998). Furthermore, the calcium, potassium, magnesium and phosphorus values determined herein were lower in general than the corresponding values of 16046.7, 17450, 2833.8 and 4827.4 mg/kg published by Olson et al. (2016) in Mexico. Freiberger et al. (1998) and Yaméogo et al. (2011) have noticed a higher calcium value (14,400 to 35,126 mg/kg) than the value determined in this experiment, and is therefore not clear what is responsible for this wide difference. Noteworthy too was the fact that the sodium content (117.4 mg/kg) reported by Olson et al. (2016) was about 99% units lower to what was determined in this experiment. These variations may be associated with such factors as soil composition, agro climatic condition, plant age and stage of maturity of the leaves, digestion protocols and analyzing techniques used as observed by Melesse et al. (2012) and Mbah et al. (2012). Phosphorus is another important macro mineral needed for rapid bone growth in meat-typed chickens. Such rapid bone growth requires adequate calcium and phosphorus supply (Williams et al., 2000).

Inadequate supply of both or one of the minerals as a result of the deficiency or excess of one of them interferes with homeostasis of the second one (Kebreab and Vitti, 2005), resulting in reduced growth rate and bone mineralization (Hurwitz et al., 1995).

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The analysed leaf meal contained small amounts of phosphorus; however, this was not a problem since the leaves were used as protein supplement for broilers. The study plant also contains appreciable quantities of iron and sulphur. This high iron content could explain the improved blood values in chickens fed MOLM based diets (Ustundag and Ozdogan, 2015; Alnidawi et al., 2016) since they are needed for haemoglobin formation. Noteworthy is that MOLM has moderate potential as a good source of dietary minerals (calcium, potassium, sodium, iron, and sulphur) in animal nutrition. High sulphur content (1144.09 mg/kg) recorded in the current study for MOLM was in agreement with Lyon et al. (2017) who reported that *Moringa oleifera* tree has an exceptional power to take up and store in the leaves mineral sulphur, even when grown on soils with low in sulphur. The health and medical benefits of this finding is that MOLM may be used to enhance productivity in animals fed low sulphur diets. The coefficient of variation of mean mineral values as observed in the current study was high, thus suggesting that the means could not serve as reference mineral value for MOLM in the study location.

The results reveal that the final live weight of starter broilers on the control birds was significantly higher than the groups on diets supplemented with MOLM at 25, 50, 75 and 100 g/kg feed, but lower than the reference live weight of 929 g recorded for 21-day-old unsexed Ross 308 broilers (www.aviagen.com). Factors such as enhanced nutrition and improved housing conditions may have explained the observed disparity in starter phase. The present result showed that MOLM supplementation up to the rate of 100 g/kg feed showed no adverse influence on feed consumption. This compared favourably with the result of Divya et al. (2014) who also noticed non-significantly reduced feed intakes in broilers fed *Moringa oleifera* leaf meal based rations. This finding indicate that the level of MOLM supplemented in the current study is acceptable to the birds. However, the reason for the acceptability is not known. Although, one possible reason is anti-nutritional factors as similarly observed by Makkar and Becker (1996). The non-significant reduction in average daily gain as observed for birds fed MOLM supplemented diets in the current feeding investigation was similar to value recorded in broilers by Divya et al. (2014). There was no significant MOLM effects on feed to gain ratio in the present feeding investigation. The result of the percentage mortality revealed that MOLM supplementation significantly influenced mortality rate ($p < 0.05$) with birds on control experiencing the highest rate. Mortality was significantly low in treatment groups relative to the control group and this observation may be because of high levels of phytochemical compounds in moringa leaves, which have been reported to have medicinal and pharmacological property such as antiprotozoal, antibacterial and antifungal effect as well as immune stimulating actions in animals (Sharma and Paliwal, 2013). Furtherance to this, the coefficient of variation of mean growth performance values were small, indicating that the reported means could be used as reference value for broilers fed diets with varying supplementation levels of MOLM in the study location.

The non-significant carcass weight and dressing percent at 25, 50, 75 and 100 g/kg feed supplementation rates can be attributed to high quality of the MOLM supplemented diets and enhanced nutrient utilisation by the broilers (Hassan et al., 2016). The result of the weights of breast, drumstick and thigh suggested that MOLM supplementation positively influenced the development of the cut parts but did not maintain progressive pattern, which is in agreement with the earlier findings published by Hassan et al. (2016). This observation has shown the suitability of MOLM supplemented diets for enhanced cut parts development and production in broilers and therefore may be recommended for broiler production. The slight enlargement on the size of the liver of broilers fed MOLM supplemented diets at 25–100 g/kg feed could be linked to enhanced activity of this organ in a bid to detoxify the antinutritional factors that may be present in the experimental diet (Igwilo et al., 2007). The weight of gizzard at 25 and 100 g/kg feed was significantly increased and this corroborated with works of Ayssiwede et al. (2011), who recorded higher gizzard weights in indigenous chickens fed MOLM based diets. In addition, the coefficient of variation of mean carcass and organ parts were narrow, suggesting that the means could serve as standard value for Ross 308 broilers fed MOLM supplemented diets in the study region.

The results of the quadratic function showed that no single MOLM supplementation level optimized FLW and ADG in the current feeding experiment. The quadratic function showed that all the significant parameters had very high (89.6–99.3%) coefficients of determination (r^2). Handful of studies has used a quadratic model to ascertain the optimal levels of feed that supported optimum performance variables in chickens (Okoro et al., 2016 a, b). However, information on the use of quadratic analysis to determining the MOLM supplementation level that supported optimum production parameters in Ross 308 broilers is lacking in the literature. The results of the quadratic function in the current study corroborate the results of Okoro et al. (2016a, b) who observed that no single feed inclusion level optimized all production parameters in chickens. The results of this feeding experiment revealed that for starter broilers, FLW and ADG was statistically optimized at 39.98 and 35.80 g/kg feed respectively. However, the value of 39.98 g/kg feed MOLM that optimized final live weight at the starter phase was 6.9 g/kg lower than the value of 46.88 g/kg that optimized the final live weight at the finisher phase. The observed difference is expected since the starter diet was high in protein (21.0%) than the finisher diet (19.0%), thus the birds on the starter phase will tend to take less diet to meet their daily protein requirements when supplemented with MOLM which are reported to contains 25.4–42.8% crude protein by Banaszkiewicz (2000) and Alnidawi et al. (2016). The high r^2 value recorded for the FLW and ADG revealed the high strength of relationship of the two variables using the quadratic analysis. These observations have practical application when supplementing diets with MOLM for FLW and ADG in Ross 308 broilers as to reduce the wastage of feed supplements. The significant optimization influence on FLW and ADG n implied that their values could be predicted at a given quantity of MOLM supplemented in the broiler diet.

Conclusion

The information provided in the current investigation further support the potential of *Moringa oleifera* leaves as an alternative non-conventional protein feed resource in broiler chicken diets. Importantly, this is useful for smallholder poultry farmers who are compelled by the high prices of conventional protein feed resource such as soybean meal to rely on such alternative protein source for enhancing the productivity of their animals. In addition, *Moringa oleifera* leaves are good sources of minerals and is suitable for cut parts development and production of enhanced cut parts in the broiler chickens. It is therefore, recommended that supplementation rate of 100 g/kg feed MOLM may be well accepted by the Ross 308 broiler chickens.

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