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Research Article
Dietary *Moringa oleifera* Leaf Meal Improves Growth Performance but not Haemo-Biochemical and Meat Quality Parameters in Female Japanese Quails

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Abstract

Background and Objective: Sustainable quail farming using readily available feed resources with nutraceutical properties has the potential to improve animal protein supply in resource-poor communities worldwide. *Moringa oleifera* leaf meal is one such feed resource that is rich in potentially beneficial bioactive and other organic compounds but has not been evaluated in quails. The study was designed to investigate the effect of dietary *Moringa oleifera* leaf meal on growth performance, haematology, serum biochemistry and carcass and meat quality traits of female Japanese quails. **Materials and Methods:** One hundred and sixty-eight female Japanese quails (196.6±3.12 g live-weights) were randomly allocated to 21 pens (100 cm long×60 cm wide×30 cm high), each holding eight birds. Three isonitrogenous and isoenergetic diets were formulated by diluting a commercial grower diet with *Moringa oleifera* leaf meal at 0 (MOLM0), 2.5 (MOLM25) and 5% (MOLM50). The three diets were randomly allocated to the 21 pens such that each diet was replicated seven times. Feed intake, weight gain and gain-to-feed ratio were determined on a weekly basis. At 6 weeks of age, all Japanese quails were taken to a local poultry abattoir for slaughter and blood collection. Haematology, serum biochemistry, carcass traits, size of internal organs and meat quality parameters were determined. **Results:** There was no week×diet interaction effect ($p>0.05$) on feed intake, weight gain and gain-to-feed ratio. Quails reared on MOLM25 had higher overall weight gain (30.72 g bird^{-1}) compared to those fed MOLM50 (18.60 g bird^{-1}) but promoted similar ($p>0.05$) overall weight gain to those fed MOLM 0 (29.28 g bird^{-1}). There was no dietary influence on all blood parameters, carcass characteristics, meat quality parameters and size of gizzards, livers, proventriculus and small intestines. Quails offered MOLM25 had longer ($p<0.05$) large intestines (13.84 cm) compared to those offered MOLM50 (11.24 cm). **Conclusion:** It was concluded that including MOLM at 2.5% improves weight gain without compromising the physiological status and meat quality of adult female Japanese quails.

Key words: Blood parameters, *Coturnix coturnix japonica*, growth performance, meat quality, *Moringa oleifera* leaf meal

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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

Quail farming is a new enterprise that complements chicken, turkey and ostrich production as sources of affordable animal protein. Eggs and meat from quails are sources of high quality dietary protein that can be used to enhance food and nutrition security, particularly in resource-poor communities of developing nations[1]. Quails are desirable sources of protein because of their excellent growth rates, early sexual maturity, short generation intervals and resistance to numerous avian diseases[2-4]. However, in order to increase quail productivity, particularly when the birds are reared under an intensive production system, a high-quality diet and disease control should be prioritized. Unfortunately, feeding cost has increased due to the direct competition for soybean and maize grain between humans, simple non-ruminants and in some cases, biofuels. In addition, the poultry industry has, over the years, relied heavily on antibiotic growth promoters (AGPs) to improve feed utilisation, gut health and overall growth performance[4]. The continued use of these AGPs has led to strong public concerns over antibiotic residues in meat and the development of pathogenic bacterial resistance[5,6], triggering their ban by the European Union in 1997[7,8]. Other feed additives such as vitamin E and selenium that are usually added to quail feeds to enhance growth performance and product quality but this approach contributes to the high cost of feeding. It is, therefore, imperative that naturally-occurring nutraceuticals are identified and evaluated as alternatives to synthetic growth promoters and feed modifiers to ensure sustainable quail production. The use of plant-based feedstuffs with possible nutraceutical properties such as *Moringa oleifera* can be a cost-effective and safe strategy to improve growth performance and product quality of intensively-reared quails. *Moringa oleifera* is a fast-growing deciduous tree from the *Moringaceae* family, known to have beneficial bioactive compounds[9,10]. Indeed, *M. oleifera* leaf meal (MOLM) is widely reported to contain significant quantities of protein, calcium, iron, phosphorus, vitamins (A, B and C) and carotenoids[11-13]. Some scholars have reported that inclusion of MOLM in broiler diets improved growth performance of broilers[14] and indigenous chickens[15]. However, its effect on growth performance, haematology, serum biochemistry and meat quality in Japanese quails is unknown. In addition to potentially beneficial chemical compounds, MOLM also contain some antinutritional factors (e.g. tannins, oxalates, saponins and phytates) that may negatively affect the physiological status of quails thus necessitating the need to monitor the haematology and serum biochemistry of quails when offered diets containing MOLM. This study was, therefore, designed to investigate the effect of *M. oleifera*-containing diets on growth performance, haematology, serum biochemistry, carcass characteristics and meat quality attributes of adult female Japanese quails. We hypothesized that dietary inclusion of MOLM would improve growth performance, blood indices and carcass and meat quality traits of the quails.

MATERIALS AND METHODS

Animal care and study site: The rearing and slaughter procedures of quails were reviewed and approved by the Animal Research Ethics Committee, North-West University (AREC-MC) (Approval No. NWU-00243-18-S5). This study was conducted at the North-West University Molelwane Research Farm (25 40.459'S, 26 10.563'E), located in the semi-arid region of the North West province of South Africa. The study was carried out in the summer season, with ambient temperatures ranging between 19 and 37°C. The area is located at an altitude of 1224 m above sea level, with an annual rainfall ranging from 300-600 mm.

Diet formulation: Fresh green *M. oleifera* leaf meal (MOLM) was supplied by Kingdom Business Investments (PTY) LTD (Gauteng, South Africa) while all other ingredients were purchased from OptiFeeds (PTY) LTD (North West, South Africa). Three isonitrogenous and isoenergetic diets were formulated by diluting a commercial grower diet with MOLM using Format® Nutritional Software as follows:

MOLM0 = Control diet (a commercial grower diet without MOLM)
MOLM25 = Control diet diluted with MOLM at a rate of 2.5%
MOLM50 = Control diet diluted with MOLM at a rate of 5.0%, as shown in Table 1

Chemical analyses: The formulated diets (MOLM0, MOLM25 and MOLM50) were milled (Polymix PX-MFC 90 D) to pass through a 1 mm sieve for chemical analyses. The diets were analysed using AOAC international methods[16] for dry matter (930.15), crude protein (984.13), crude fiber (978.10) and crude fat (920.39). Metabolisable energy contents were predicted using models from the near infrared reflectance spectroscopy (SpectraStar XL, Unity Scientific, Australia). Mineral contents (calcium, phosphorus, sodium and potassium) were analyzed following the Agri-Laboratory Association of Southern Africa guidelines[17].

Table 1: Ingredient and chemical composition (g kg^{-1} as fed basis, unless otherwise stated) of *Moringa oleifera* leaf meal-containing diets

	Diets[1]		
	CON	MOLM25	MOLM50
Moringa oleifera leaf meal	0.00	25.00	50.00
Yellow maize-fine	698.60	679.20	659.80
Prime gluten 60	18.00	18.00	18.00
Full fat soya meal	50.70	81.60	113.10
Soybean meal	196.70	160.20	123.10
Limestone powder	14.50	14.50	14.50
Mono calcium phosphate	7.20	7.20	7.20
Salt-fine	3.20	3.20	3.20
Sodium bicarbonate	1.70	1.70	1.70
Choline powder	0.80	0.80	0.80
Lysine	2.80	2.80	2.80
L-Threonine	0.40	0.40	0.40
Methionine	1.90	1.90	1.90
Grower-phytase	1.70	1.70	1.70
Premix	0.50	0.50	0.50
Olaquindox	0.40	0.40	0.40
Chemical composition			
Dry matter	901.60	903.10	904.60
ME (MJ kg^{-1})	12.11	12.13	12.15
Crude protein	183.00	183.00	183.00
Crude fat	47.40	52.80	58.30
Crude fiber	25.80	26.80	27.70
Calcium	7.20	7.20	7.20
Phosphorus	4.50	4.50	4.40
Sodium	1.80	1.80	1.80
Potassium	7.30	7.30	7.30

[1]Diets; CON: Control diet (a commercial grower diet without MOLM), MOLM25: Control diet diluted with MOLM at a rate of 2.5%, MOLM50: Control diet diluted with MOLM at a rate of 5.0%

Feeding trial: Three-week-old, mixed-gender Japanese quails were purchased from Quail Breeders (Gauteng, South Africa). The quails were reared until five weeks of age to allow for gender differentiation using a commercial grower-mash diet purchased from Opti Feeds (PTY) LTD (North West, South Africa). At five weeks of age, a total of 168 female birds were attained upon gender sexing. The females were randomly allocated to 21 pens (experimental units) each holding eight birds. The three experimental diets were randomly allocated to the pens and thus each diet was replicated seven times. The size of each pen was 100 cm long × 60 cm wide × 30 cm high. The birds were allowed to adapt to the pens and dietary treatments for a week before measurements commenced.

Feed intake and growth performance: Average weekly feed intake (AWFI) per bird was measured by subtracting the weight of the feed refused from that of the feed offered and dividing the difference by the total number of quails in the pen. Live weights were measured weekly by weighing all the quails in each pen. These liveweights were used to calculate the average weekly weight gain (AWG) per bird. Average weekly gain-to-feed ratio (G:F) was determined as:

$$G:F = \frac{AWG}{AWFI}$$

Slaughter procedure and blood parameters: At 10 weeks of age, all Japanese quails were taken to a local poultry abattoir (North West, South Africa) for slaughter. At the abattoir, all the quails were electrically stunned, then slaughtered by cutting the jugular vein with a sharp knife and left hanging on a metal rack until bleeding ended. After slaughtering, the birds were put through a de-feathering machine and packaged per experimental unit. During bleeding, about 4 mL of blood was separately collected from two quails randomly selected from each pen into two sets of sterilized tubes. Purple-top tubes containing EDTA as an anti-coagulant were used for haematology, whereas red-top tubes without anticoagulant were used for serum biochemistry. Haematological parameters (erythrocytes, haemoglobin, haematocrits, leucocytes, lymphocytes, monocytes and neutrophils) were determined using an automated IDEXX LaserCyte Haematology Analyzer (IDEXX Laboratories, Inc.). Clotted blood was centrifuged in a macro-centrifuge (Hermle Labortechnik GmbH, Germany) at 1000 g for 15 min to generate serum for biochemical analysis according to Buetow *et al.*[18]. Serum biochemical parameters (albumin, alanine transaminase, total bilirubin, cholesterol, glucose, lipase and total protein) were analyzed using an automated IDEXX Vet Test Chemistry Analyzer (IDEXX Laboratories, Inc.).

Internal organs and carcass characteristics: The carcasses were taken to the Animal Science laboratory of the North-West University for determination of internal organ size and carcass characteristics. The weights of gizzards, livers, thighs, proventriculus and wings were measured using a digital weighing scale (Explorer® EX224, OHAUS Corp, US). The lengths of small and large intestines were determined using a measuring tape. The carcasses were immediately weighed to obtain the hot carcass weights (HCW) and after chilling for 24 h they were reweighed to obtain the cold carcass weights (CCW). The dressing out percentage was determined as the proportion of hot carcass weight (HCW) on slaughter weight.

Meat quality measurements

Meat pH and colour: Post mortem pH was measured using a Corning Model 4 pH-temperature meter (Corning Glass Works, Med field, MA) equipped with an Ingold spear-type electrode (Ingold Messtechnik AG, Udorf, Switzerland). After every 20 measurements, the pH meter was calibrated with standard solutions (Ingold Messtechnik AG, Udorf, Switzerland). Colour of the meat (L* = Lightness, a* = Redness and

b* = Yellowness) was determined 24 h after slaughter, using a Minolta colour-guide (BYK-Gardener GmbH, Geretsried, Germany), with a 20 mm diameter measurement area and illuminant D65-day light, 10° observation angle[19]. The colour meter was calibrated using the green standard before measurements. Colour recording was done on the surface of the thigh muscle, which was allowed to bloom for 1 h on a polystyrene tray at 4°C. Hue angle was calculated as $\tan^{-1}$ (b*/a*) and Chroma was calculated as the square root of $a^{*2}+b^{*2}$.

Cooking losses and Shear force: For cooking loss determination, breast samples were pre-weighed and placed in an oven set at 130°C for 20 min and thereafter weighed to attain final weight as guided by Honikel[20]. The following formula was employed:

$$\text{Cooking losses}(\%) = \frac{\text{Initial weight}(g)\text{-final weight}(g)}{\text{Initial weight}(g)} \times 100$$

After determination of cooking loss, the same breast samples were sheared perpendicular to the fibre direction using a Meullenet-Owens razor shear blade mounted on an Universal Instron apparatus (cross head speed = 200 mm min^{-1}, one shear in the centre of each core). The reported value represented the average positive peak force measurements of each sample.

Water holding capacity and drip loss: The water holding capacity (WHC) of breast samples (8 g) were determined as the amount of water expressed from the meat held under pressure (60 kg pressure) using the filter-paper press method[21]. The water from the fresh meat was absorbed by a pre-weighed filter paper and calculated as the proportion of the initial weight of the slice of breast muscle. Water holding capacity was calculated using the equation:

$$\text{WHC}(\%) = \frac{\text{initial weight-weight after pressing}}{\text{initial weight}} \times 100$$

For drip loss measurement, pieces of breast muscle (W1; 2 g) were hooked and suspended using wire steel in a plastic bottle and sealed properly so that the samples did not touch the sides of the bottle. The suspended samples were stored in a cold room (4°C) for 72 h. The breast samples were reweighed to obtain weight after drip (W2) and the difference in weight of each sample before and after drip was taken as percentage drip loss. The difference in weight of each sample before and after drip was conveyed as percentage drip loss and calculated as follows:

$$\text{Drip loss}(\%) = \left[\frac{(W1 - W2)}{W1}\right] \times 100$$

Statistical analyses: Data for each parameter collected per replicate pen were averaged first before statistical analysis. All reported parameters were tested for normality using the NORMAL option in the Proc Univariate statement before being subjected to analysis of variance. Average weekly feed intake, average weekly weight gain and average weekly G:F data were analyzed using repeated measures procedure of SAS[22]. The following statistical linear model was employed:

$$Y_{ijk} = \mu + D_i + W_j + (D \times W)_{ij} + E_{ijk}$$

Where

Y_{ijk} = Dependent variable
μ = Population mean
D_i = Effect of diets
W_j = Effect of week
$D \times W_{ij}$ = Effect of interaction between diets and week
E_{ijk} = Random error associated with observation ijk, assumed to be normally and independently distributed

The dietary effect on overall feed intake, overall weight gain, overall G:F, blood parameters, carcass characteristics and meat quality parameters were analyzed using the GLM procedure of SAS[22]. The linear statistical model was as follows:

$$Y_{ik} = \mu + D_i + E_{ik}$$

Where

Y_{ik} = Dependent variable
μ = Population mean
D_i = Effect of diets
E_{ik} = Random error associated with observation ik

Assumed to be normally and independently distributed. For all statistical tests, significance was declared at $p<0.05$. Least squares means (LSMEANS) were compared using the probability of difference option in the LSMEANS statement of SAS.

Table 2: Overall feed intake (g bird^{-1}), overall weight gain (g bird^{-1}) and overall feed conversion efficiency in Japanese quails fed graded levels of *Moringa oleifera* leaf meal

	[1]Diets				
	MOLM0	MOLM25	MOLM50	[2]SEM	[3]Significance
Overall feed intake	847.300	871.700	870.600	32.800	NS
Overall weight gain	29.280^{ab}	30.720^{b}	18.600^{a}	2.680	*
Overall G:F	0.139	0.141	0.088	0.014	NS

[1]Diets: MOLM0: Control diet (a commercial grower diet without MOLM), MOLM25: Control diet diluted with MOLM at a rate of 2.5%, MOLM50: Control diet diluted with MOLM at a rate of 5.0%, [2]SEM: Standard error of the mean, [3]Significance: NS: Not significant, *p 0.05. ^{a,b}In a row, dietary treatment means with common superscripts do not differ (p>0.05)

RESULTS

Table 2 shows the overall feed intake, overall weight gain and overall gain-to-feed ratio of Japanese quails. Dietary treatments had no effect (p>0.05) on overall feed intake and overall G : F except for overall weight gain. Quails fed MOLM25 had higher (p 0.05) overall weight gain (30.72 g bird^{-1}) compared to those fed MOLM50 (18.60 g bird^{-1}). Diets MOLM0 and MOLM50 promoted similar (p>0.05) overall weight gain in Japanese quails. Table 3 shows blood parameters of Japanese quails fed MOLM-containing diets. There was no dietary influence (p>0.05) on all hematological and serum biochemical parameters of quails.

Table 4 shows the internal organs of Japanese quails fed MOLM-containing diets. Diets had no significant influence on weights of gizzards, livers and proventriculus and length of small intestines. However, dietary treatments had influence (p<0.05) on the lengths of large intestines. Quails offered diet MOLM25 and MOLM0 had longer large intestines compared to those offered MOLM50. Table 5 shows that diets had no effect on weights of the thighs, wings, HCW and CCW as well as the dressing percentage of quails. Table 6 shows that diets had no significant effect on meat pH, meat colour (L*, a*, b*, chroma, hue angle), shear force, cooking loss, drip loss and water holding capacity measured 24 h post mortem.

Table 3: The effect of *Moringa oleifera* leaf meal-containing diets on haemato-biochemical indices of Japanese quails

	[1]Diets			
	MOLM0	MOLM25	MOLM50	[2]SEM
Hematological parameters				
Erythrocytes ($\times 10^{12}$ L^{-1})	2.83	3.06	3.17	0.159
Hematocrits (L L^{-1})	0.44	0.51	0.50	0.024
Hemoglobin (g dL^{-1})	14.32	14.85	13.70	0.452
Leucocytes ($\times 10^{9}$ L^{-1})	23.86	34.88	32.41	4.310
Lymphocytes ($\times 10^{9}$ L^{-1})	17.28	26.84	19.33	3.190
Monocytes ($\times 10^{9}$ L^{-1})	3.02	1.22	4.22	0.751
Neutrophils ($\times 10^{9}$ L^{-1})	3.30	5.60	11.05	3.230
Serum biochemical indices				
Albumin (g L^{-1})	13.71	12.79	13.21	0.608
Alanine transaminase (U L^{-1})	13.50	14.71	15.78	2.394
Total bilirubin (µmol L^{-1})	5.00	5.00	4.53	0.150
Cholesterol (mmol L^{-1})	5.13	6.24	5.46	0.504
Glucose (mmol L^{-1})	14.31	13.57	12.12	0.979
Lipase (U L^{-1})	57.50	63.78	56.21	6.970
Total protein (g L^{-1})	39.21	34.79	36.78	1.610

[1]Diets; MOLM0: Control diet (a commercial grower diet without MOLM), MOLM25: Control diet diluted with MOLM at a rate of 2.5%, MOLM50: Control diet diluted with MOLM at a rate of 5.0%, [2]SEM: Standard error of the mean

DISCUSSION

Growth performance: The current study was conducted to evaluate the effect of graded inclusion levels of *M. oleifera* leaf meal on growth performance, haematology, serum biochemistry, carcass characteristics and meat quality parameters of Japanese quails. Repeated measures analysis showed no week×diet interaction effect on AWFI, AWG and G:F, indicating that the effect of graded levels of MOLM-containing diets on these parameters did not depend on the age of quails. Quails offered diet MOLM25 had higher overall weight gain (30.72 g bird^{-1}) compared to those fed MOLM50 (18.60 g bird^{-1}), suggesting that adding MOLM at 5% compromises growth rate. Including MOLM beyond the 2.5% levels compromised growth performance of the quails, which can be attributed to high levels of antinutritional compounds (fibre, tannins, oxalate, saponins and phytates)[23]. However, quails offered MOLM25 had similar (p>0.05) overall weight gain with those offered the control diet (MOLM0), which was unexpected given that MOLM has been reported to improve weight gain in other avian species due to the presence of growth-boosting bioactive compounds such as carotenoids, vitamins, minerals, amino acids, alkaloids and flavonoids[1,5,24].

Haematological and serum biochemical parameters: Blood indices are essential indicators of pathophysiological status of animals, providing a clinical monitoring of their health[25]. In this study, the lack of dietary effects suggests that dietary inclusion of MOLM did not compromise the health status of quails, with all reported values falling within the normal ranges for adult female Japanese quails[2]. Indeed, the level of alanine transaminase, which is an enzyme that indicates liver damage,

Table 4: Size of internal organs of 10-week old Japanese quails fed graded levels of *Moringa oleifera* leaf meal containing diets

	[1]Diets				
	MOLM0	MOLM25	MOLM50	[2]SEM	[3]Significance
Large intestines (cm)	12.73[ab]	13.84[b]	11.24[a]	0.622	*
Small intestines (cm)	45.37	45.15	43.89	1.360	NS
Gizzards (g)	3.37	3.25	3.34	0.131	NS
Livers (g)	4.56	4.47	3.82	0.285	NS
Proventiculi (g)	0.86	0.79	0.80	0.041	NS

[1]Diets; MOLM0: control diet (a commercial grower diet without MOLM), MOLM25: Control diet diluted with MOLM at a rate of 2.5%, MOLM50: Control diet diluted with MOLM at a rate of 5.0%, [2]SEM: Standard error of the mean, [3]Significance: NS: Not significant, *p<0.05. [a,b]In a row, dietary treatment means with common superscripts do not differ (p>0.05)

Table 5: The effect of graded levels of *Moringa oleifera* leaf meal on carcass characteristics of 10-week old Japanese quails

	[1]Diets			
	MOLM0	MOLM25	MOLM50	[4]SEM
Thighs (g)	6.37	5.91	5.56	0.213
Wings (g)	6.35	5.79	5.41	0.323
[2]HCW (g)	142.40	130.60	127.80	5.030
[3]CCW (g)	139.70	127.70	126.10	4.620
Dressing (%)	62.70	58.71	62.22	2.020

[1]Diets; MOLM0: Control diet (a commercial grower diet without MOLM); MOLM25: Control diet diluted with MOLM at a rate of 2.5%, MOLM50: Control diet diluted with MOLM at a rate of 5.0%, [2]HCW: Hot carcass weight, [3]CCW: Cold carcass weight, [4]SEM: Standard error of the mean

Table 6: The effect of graded levels of *Moringa oleifera* leaf meal on meat quality parameters Japanese quails 24 h after slaughter

	[1]Diets			
	MOLM0	MOLM25	MOLM50	[3]SEM
pH	6.65	7.62	6.70	0.524
L*	48.71	42.41	48.50	3.700
a*	4.19	4.78	6.44	1.050
b*	9.57	9.05	10.58	1.190
Chroma	5.19	5.11	5.58	0.293
Hue angle	1.12	1.14	1.04	0.052
Shear force (N)	5.92	5.77	5.84	0.583
Cooking loss (%)	44.80	43.37	43.19	1.407
Drip loss (%)	19.26	19.30	20.41	1.427
[2]WHC (%)	7.14	7.59	6.46	1.250

[1]Diets; MOLM0: Control diet (a commercial grower diet without MOLM), MOLM25: Control diet diluted with MOLM at a rate of 2.5%, MOLM50: Control diet diluted with MOLM at a rate of 5.0%, [2]WHC: Water holding capacity, [3]SEM: Standard error of the mean

was similar across all diets. This indicates that inclusion of MOLM did not introduce large amounts of toxic compounds that could have induced abnormal liver function in a detoxifying effort.

Size of internal organs and meat quality: Among all internal organs measured, dietary treatments only influenced the lengths of large intestines. Quails offered diet MOLM25 had longer large intestines compared to those offered MOLM50, which was surprising because MOLM50 had more fiber thus was expected to cause the enlargement of intestines as an adaptive mechanism[26]. Diets had no effect on weights of the thighs, wings, HCW and CCW as well as the dressing percentage of quails, which was consistent with the findings of Cui *et al.*[27] who reported no significant responses on carcass traits in broilers fed MOLM-containing diets. For meat quality parameters, diets had no significant effect on meat pH, meat colour (L*, a*, b*, chroma, hue angle), shear force, cooking loss, drip loss and water holding capacity measured 24 h post mortem. The lack of effects indicates the potential of moringa to promote normal oxidative stability for meat quality attributes during storage, which was consistent with the findings of Qwele *et al.*[28]. The lack of change in meat color upon dietary inclusion of MOLM, while surprising given the presence of pigments in the leaf meal, could have been due to the low inclusion levels (2.5 and 5%) used for MOLM. Indeed, Ncube *et al.*[29] only observed a change in meat color when broilers were offered diets containing 10% *Acacia angustissima* leaf meal.

CONCLUSION

The inclusion of *M. oleifera* leaf meal at 2.5% promoted weight gain of female Japanese quails, indicating that MOLM may be included in adult female quail diets at this level. Inclusion of MOLM in a commercial grower diet had no effect on blood and meat quality parameters, suggesting that dietary use of the leaf meal for adult female Japanese quails does not compromise their performance and pathophysiological status. The inclusion of MOLM, an environmentally friendly feed additive, in quail diets will contribute to the production of antibiotic residue-free poultry products, thereby protecting the health of consumers.

SIGNIFICANCE STATEMENT

This study revealed that inclusion of moringa at 2.5% improved overall weight gain of Japanese quails. Some

internal organ sizes were also altered by the supplementation of moringa. However, no dietary effects were observed on carcass and meat quality traits.

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