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Impact of supplementing duck diets with Moringa (*Moringa Oleifera*) leaves

Ghada S.E. Abdel-Raheem[1], Aya M.A. Ahmed[1], Abdel baset N.S. Ahmed[1], Fares A. Eldeeb[2*]

[1]*Departments of Nutrition and Clinical Nutrition, Faculty of Veterinary Medicine, Assiut University 71515, Egypt.*
[2]*Department of Nutrition and Clinical Nutrition, Faculty of Veterinary Medicine, Aswan University, Aswan 81528, Egypt.*

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***Correspondence:**

Corresponding author: Fares A. Eldeeb
E-mail address: FaresAli@vet.aswu.edu.eg

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ABSTRACT

The present work was carried out to study the effect of different levels of *Moringa Oleifera* leaf meal (MOLM) content as untraditional feedingstuff constituents on ducks performance, carcass traits, blood biochemical parameters and meat chemical composition. A total of 50 mulard ducklings (two weeks old) were randomly divided into 5 groups of 10 ducklings each. The first group was considered the control group (T1) and was fed ad-libitum on a grower-finisher diets. The remaining four groups (T2, T3, T4 and T5) were fed on diets containing MOLM at levels of 2%, 4%, 6% and 8%, respectively. All diets were formulated to be isocaloric (3000 kcal/kg ME) and isonitrogenous (16% CP). The experiment was extended for 8 weeks. Growth performance parameters include body weight, weight gain, feed consumption, feed-to-gain ratio, relative growth rate, performance index, crude protein intake, protein efficiency ratio, metabolizable energy intake and calorie efficiency ratio were all recorded. At the end of the experiment, three randomly selected ducks were slaughtered to evaluate carcass characteristics, meat chemical composition and blood biochemical parameters. Results showed that there were no mortalities between ducks in all groups along the experimental periods. Ducks fed diets containing 2 and 4% MOLM had higher in body weight and weight gain than ducks fed diets containing 6 and 8% MOLM. Feeding of different levels of MOLM to ducklings had no significant effect on feed consumption. The best feed conversion ratio was recorded in group T3 followed by group T2 compared to other tested groups and control T1. Ducks in group T3 fed on 4% MOLM showed improvements in their relative growth rate (RGR) and performance index (PI) compared to other tested and control groups. There were no significant ($P>0.05$) differences between the control group and the other tested groups in terms of crude protein intake and protein efficiency ratio, as well as metabolizable energy intake and calorie efficiency ratio of ducks. Pre-slaughter weight, eviscerated weight and dressing weight were significantly higher in groups T2, T3 and T4 fed (2%, 4% and 6%) MOLM compared to those fed on 8% MOLM and control diets. There were no significant differences in the relative weights of the internal organs (liver, heart, proventriculus, gizzard and spleen). Supplementation of duck diets with MOLM significantly ($P<0.05$) increased DM, CP and EE of the breast and thigh meat compared to the control group, while ash content was not affected. There were no significant ($p<0.05$) differences between different experimental groups in hematological pictures, except for WBCs, lymphocytic count, mean corpuscular hemoglobin concentration (MCHC), hematocrit (HCT) and platelets (Plt). Inclusion of MOLM in duck diets reduced the serum cholesterol and triglyceride concentrations, while the serum total protein and its fractions (albumin and globulin) were not affected. It was concluded that supplementation of *Moringa Oleifera* leaf meal (MOLM) in duck diets had beneficial effects on the growth performance parameters, meat composition and carcass characteristics, as well as improved the immunity by increasing the number of white blood cells and lymphocytes and reduced serum triglycerides and cholesterol concentrations.

Introduction

The global poultry industry faces many obstacles, the most important of which is the high price of feed ingredients (Abbas, 2013), therefore, it is necessary not only to find inexpensive sources of protein or energy, but also to look for ingredients with high medicinal value or high-quality proteins, energy and vitamins to try to remove some of these obstacles, especially especially in developing countries.

Antibiotics are used as growth promoters at subtherapeutic levels and to treat poultry diseases. However, the use of antibiotics can cause problems such as drug toxicity, residual effects and the development of bacterial resistance. This has led to a ban on the use of antibiotics as growth promoters since 2006 by the European Union (Ogbe and Affiku, 2011). Therefore, phytobiotics have attracted attention in the field of animal nutrition as alternatives to growth-promoting antibiotics (Puvača *et al*., 2013). They have been shown to stimulate food intake, activate digestion, improve the immune system and have anti-coccidial, anti-helminthic and antibacterial properties (Panda *et al*., 2006).

Moringa Oleifera Lam., belonging to the Moringaceae family, is known to contain 30.3% crude protein, including 19 amino acids (Moyo *et al*., 2011), 2273 - 2978 kcal/kg dry matter, metabolizable energy (Olugbemi *et al*., 2010), vitamins (A, B, C and E), 0.6 - 11.2% minerals (Mbora *et al*., 2004), 1.28 - 4.96% lipids (Mehta *et al*., 2003), 30.97 - 46.78% dietary fiber (Sánchez-Machado *et al*., 2010) and high levels of flavonoids as antioxidants (Vongsak *et al*., 2013). Therefore, the use of *M. Oleifera* in poultry feed is of increasing interest. Therefore, the demand for M. Olifera is increasing (Abou Sekken, 2015). Previous studies have shown that replacing antibiotic growth promoters with *M. Oleifera* leaf meal (OMLM) has beneficial effects on growth performance and carcass yield of broiler chickens (David *et al*., 2012).

Ducks and geese will become increasingly important in reducing hunger and improving food security for many rural families (Pingel, 2011). Using *Moringa Oleifera* leaf powder as a natural growth stimulant, improves growth performance, nutrient digestibility coefficient and consumer acceptability of duck meat (Abd-El-Samee *et al*., 2019).

Despite the high crude protein content of *Moringa Oleifera* leaf meal, little information is available on its use as unconventional feed resource, especially as an alternative protein supplement for duck production. Therefore, this study was conducted to study the effect of different levels of *Moringa Oleifera* leaf meal as untraditional feedingstuff constituent on duck performance, carcass characteristics, blood biochemical parameters and chemical composition of meat.

Materials and methods

Ethical Approval

The materials and procedures applied in this study were accepted

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by the Scientific Research Ethics Committee of the Faculty of Veterinary Medicine, Assiut University, Assiut, Egypt, and carry the approval number (aun/vet/3/0014).

Study period and location

The experimental study was conducted for 8 weeks at a duck farm in New Valley Governorate, Qena, Egypt.

Experimental birds and management

50 Mulard unsexed ducklings were used for the experiment. Ducklings were two weeks old and had similar average initial weight (411.10 g – 431.50 g). Ducklings were leg-banned, individually weighted and randomly divided into 5 groups of 10 ducklings each. Ducklings were vaccinated against avian influenza Virus (H5N2) (on day 7). The experimental room was disinfected with 0.5% TH4 and divided into 5 compartments, each with floor area of 2.5 m2 using sawdust as bedding material. Feeders and water fountains were distributed throughout the experimental compartments. Feed and fresh water were provided ad-libitum throughout the rearing period.

Processing of Moringa leaves

Freshly harvested green Moringa leaves have been air-dried without exposure to direct sunlight, stirred continuously to prevent fungal growth until they are crisp to the touch, while still remaining green. The leaves were grinded into a fine powder to pass through a 15 mm sieve. The leaf meal was packed tightly in a polyethylene plastic bag, sealed and stored at 4°C. Chemical composition and Metabolizable energy value of MOLM according to Tijani *et al*. (2016) are presented in Table 1.

Table 1. Chemical composition and metabolizable energy value of MOLM used in the experiment.

Item	Chemical composition (%)						ME(Kcal/kg)
	DM	CP	EE	CF	NFE	Ash	
MOLM	92.5	35.2	6.2	11	28.9	11.2	3271

Experimental diet

Five experimental diets were formulated as grower-finisher diets to contain approximately 16% crude protein and 3000 metabolizable energy Kcal/Kg diet as recommended by NRC (1994). Diet 1, which was designated as T1 served as the control diet with no moringa leaf meal, while T2, T3, T4, T5 supplemented with *M. Oleifera* leaves meal at different levels 2, 4, 6% and 8%, respectively. Physical and chemical compositions and energy values of the experimental diet are presented in Table 2.

Feed Analysis

Chemical analysis of the diet ingredients was performed to determine DM, CP, EE, CF, ash and NFE according to the Association of Official Analytical Chemists method (AOAC, 2003). ME content in feed ingredients and experimental diets was calculated based on the chemical composition (NRC, 1994).

Performance measurement

The average live bird body weight was detected weekly by weighing the birds; as well as their feed consumption. Based on live body weight and feed consumption of ducks; several indices have been calculated as indicators of duck performance, including: body weight gain (Brady, 1968); feed to gain ratio (feed conversion ratio) and performance index (Soliman and Hassan, 2017); realtive growth rate (Crampton and Lioyd, 1959).

From calculation of crude protein intake for each group [CPI (g) = Feed intake (g) × crude protein in ration (%)], protein efficiency ratio (PER) was calculated [PER = Body weight gain (g) / CPI (g)]. Also, From calculation of metabolizable energy intake for each group [MEI (kcal) = Feed intake (g) × Metabolizable energy in ration (Kcal/kg diet) / 1000], Caloric efficiency ratio (CER) was calculated [CER = MEI (kcal) / Body weight gain (g)].

Table 2. Physical and chemical compositions and energy values of the experimental basal diet.

Ingredients	Treatment (MOLM)				
	T1 0%	T2 2%	T3 4%	T4 6%	T5 8%
Physical composition:					
Yellow Corn, ground	51.25	51.5	51.82	52.05	52.4
Soybean meal (46%)	18.3	16.7	15.05	13.45	11.84
Wheat bran	20	20	20	20	20
Sunflower oil	7.15	6.71	6.25	5.83	5.3
Moringa leaves	0	2	4	6	8
Dibasic sodium phosphate	1.3	1.3	1.3	1.3	1.3
Ground limestone	1.35	1.15	0.95	0.75	0.55
Common salt	0.3	0.3	0.3	0.3	0.3
Methionine	0.05	0.04	0.03	0.02	0.01
Premix*	0.3	0.3	0.3	0.3	0.3
Chemical composition:					
Crude protein	16.01	16.01	16.01	16	16.04
Calcium	0.6	0.6	0.58	0.58	0.6
Available phosphorus	0.4	0.41	0.4	0.41	0.41
Lysine	0.74	0.77	0.79	0.84	0.84
Methionine	0.3	0.3	0.3	0.3	0.3
ME (Kcal/kg diet)	3000	3000	3000	3000	3000

*Premix, each 3 kg contain: Vit. A 120000 IU, Vit. D3 300000 IU, Vit. E700 mg, Vit. K3 500 mg, Vit. B1 500 mg, Vit. B2 500 mg, Vit. B6 600 mg, Vit. B12 3 mg, Pantothenic acid 670 mg, Niacin 300 mg, Folic acid 300 mg, Biotin 6 mg, iron sulphate 10000 mg, Manganese sulphate 3000 mg, Choline chloride 1000 mg, Iodine 10 mg, Copper sulphate 3000 mg, Selenium 1 mg and Zinc sulphate 1800 mg, cobalt sulphate, 300 mg.

Carcass characteristics

At the end of the experiment, three randomly selected birds from each group were slaughtered after an overnight fast. The weight of the hot carcass and dressed carcass (the weight of the slaughtered bird after the feathers have been removed, the head and feet raised including all the edible viscera) were recorded. The weights of some internal organs including the heart, spleen, liver and proventriculus were also recorded. Data were also expressed as relative weight of live body weight. Dressing percentage was calculated by dividing the weight of dressed carcass by live body weight multiplied by one hundred (Batta, 2004).

Meat chemical composition

Breast and thigh meat samples from slaughtered birds in all experimental groups were collected separately, prepared (carefully minced) and chemically analyzed for dry matter, crude protein, ether extract and ash according to AOAC (2003) official method.

Hematological picture and serum biochemical Assay

Blood samples were collected from slaughtered ducks in clearly labeled and sterilized tubes containing EDTA to determine hematological parameters as described by standard method of Schalm *et al.* (1975). Blood samples for serum extraction were collected in test tubes and

placed at room temperature, centrifuged for 15 minutes at 3000 rpm. Serum samples were stored at -20ºc until for analysis. Serum samples were analyzed for total protein and its fractions (albumin and globulin) based on the method described by Kaplan and Pesce (1996), triglycerides and cholesterol by spectrophotometer with the commercial test kits (Spectrum, Cairo, Egypt).

Statistical Analysis

The obtained results were expressed as the mean ± standard error. All data were analyzed using one analysis of variance (ANOVA) followed by Duncan's test using the SPSS 20.0 statistical package for social science software (SPSS, 2009).

Results

Performance parameters

The effect of supplementing *Moringa Oleifera* leaf meal (MOLM) on duck performance is presented in Table 3. Ducks fed diets contatining 2 and 4% MOLM had significantly (P<0.05) higher final body weight and total body weight gain than ducks fed diets containing 6 and 8% MOLM. Supplementation of different levels of MOLM to ducklings had no significant effect on feed consumption. The best feed conversion value was recorded in T3 followed by T2 groups (3.14 and 3.31, respectively) which fed on diets contatining 4% and 2% MOLM, respectively compared to T1, T4 and T5 groups (3.56, 3.58 and 3.72, respectively) which fed diets supplemented with 0%, 6% and 8% MOLM, respectively. There were significant (P<0.05) differences in relative growth rate (RGR) and performance index (PI) between experimental groups and control. Inclusion of 4% and 2% MOLM in duck diets resulted in a significant improvements in relative growth rate (RGR) and performance index (PI) compared to other experimental and control groups. Regarding the crude protein intake and protein efficiency ratio, as well as metabolizable energy intake and caloric efficiency ratio of ducks, the results showed no significant (P>0.05) differences between the control and other experimental groups throughout the whole experimental period. Numerically, the lowest values of protein and energy intake were recorded by group fed 8% MOLM, while the highest values were recorded by the group fed 4% MOLM.

Carcass characteristics

Results of duck carcass characteristics are presented in Table 4. Pre-slaughter weight, eviscerated weight and dressing weight increased significantly (P<0.05) in the T2, T3, T4 groups fed diets contatining 2%, 4% and 6% MOLM compared to the group fed 8% MOLM (T5) and control (T1) diets. There were no significant differences in the relative weights of liver, heart, proventriculus, gizzard and spleen in ducks fed MOLM supplemented diet compared to the control. Regarding the influence of dietary MOLM levels on the carcass chemical composition, the results in Table 5 indicate that, there were significant differences (P<0.05) in DM, CP and EE contents of duck meat in all experimental groups. MOLM supplementation of significantly (P<0.05) increased DM, CP and EE of breast and thigh meat compared to the control group, while ash content was not affected.

Hematological traits

The effect of MOLM on hematological traits of ducks are summarized in Table 6. The results showed no significant differences (p>0.05)

Table 3. Performance parameters of ducks during the experiment.

Parameters	T1	T2	T3	T4	T5
Initial body weight (g)	419.6±21.7	431.5±24.5	411.1±20.4	413.7±25.5	418.8±27.9
Final body weight (g)	3106.2±59.9^{b}	3237.0±79.7^{ab}	3441.0±72.4^{a}	3031.0±82.3^{bc}	2897.7±92.4^{c*}
Total body weight gain (g)	2686.6±27.1^{b}	2805.5±34.7^{ab}	3029.9±20.3^{a}	2617.3±18.5^{bc}	2478.9±25.4^{c}
Total feed intake (g)	9573	9299	9518	9383	9229
Feed conversion ratio (g feed/ g weight gain)	3.56±0.38^{b}	3.31±0.27^{bc}	3.14±0.16^{c}	3.58±0.30^{ab}	3.72±0.40^{a}
Relative growth rate (g)	152.4±5.6^{b}	153.0±5.3^{ab}	157.3±5.8^{a}	152.0±5.1^{bc}	149.5±5.4^{c}
Performance index (%)	87.3±11.6^{b}	97.8±15.3^{ab}	109.6±19.7^{a}	84.7±10.5^{bc}	77.9±12.8^{c}
Crude protein intake (g)	1532.6±25.9	1488.8±26.3	1523.8±24.0	1501.3±28.4	1480.3±23.7
Protein efficiency ratio	1.75±0.20	1.88±0.16	1.99±0.13	1.74±0.18	1.67±0.26
Metabolizable energy intake (kcal)	28719±42.4	27897±43.5	28554±44.9	28149±47.8	27687±40.0
Caloric efficiency ratio	10.7±1.2	9.9±0.9	9.4±1.8	10.8±1.1	11.2±1.4

T1: control group fed basal diet without any supplementation; T2: 2% MOLM; T3: 4% MOLM; T4: 6% MOLM; T5: 8% MOLM.
*Means within the same raw with different superscripts are significantly different (P<0.05).

Table 4. Carcass characteristics and relative weights of some organs (%) of ducks during the experiment.

Parameters	T1	T2	T3	T4	T5
Pre-slaughter wt. (g)	3162.70±33.35^{bc}	3463.33±40.83^{ab}	3488.30±27.83^{a}	3317.33±46.15^{b}	3070.70±63.05^{c}
Eviscerated wt. (g)	2232.33±12.77^{bc}	2470.70±17.25^{ab}	2532.70±23.36^{a}	2347.30±36.47^{b}	2231.00±19.80^{c}
Eviscerated (%)	70.58±0.23	71.34±1.44	72.61±0.88	70.76±0.45	72.65±1.31
Dressing wt. (g)	2416.00±15.39^{bc}	2654.33±21.73^{ab}	2724.33±28.15^{a}	2526.33±40.43^{b}	2407.33±21.50^{c}
Dressing (%)	76.39±0.40	76.64±3.16	78.10±0.17	76.16±0.31	78.40±1.09
Liver (%)	2.25±0.31	2.27±0.03	2.37±0.04	2.32±0.09	2.30±0.03
Heart (%)	0.76±0.03	0.78±0.03	0.82±0.02	0.76±0.02	0.80±0.15
Proventriculus (%)	0.30±0.10	0.29±0.02	0.34±0.04	0.29±0.01	0.30±0.02
Gizzard (%)	2.63±0.03	2.71±0.03	2.62±0.19	2.70±0.02	2.71±0.04
Spleen (%)	0.08±0.03	0.09±0.07	0.09±0.07	0.09±0.07	0.09±0.07

T1: control group fed basal diet without any supplementation; T2: 2% MOLM; T3: 4% MOLM; T4: 6% MOLM; T5: 8% MOLM.
*Means within the same raw with different superscripts are significantly different (P<0.05).

between all experimental groups in hemoglobin (Hb), mean corpuscular hemoglobin (MCH), RBCs, mean corpuscular volume (MCV) and Hematocrit (HCT). However, there were significant differences ($p<0.05$) in WBCs, lymphocytic count, mean corpuscular hemoglobin concentration (MCHC) and platelets. The highest numbers of WBCs and platelets were in T2, T3 and T4 groups.

Serum biochemical parameters

Statistical analysis of serum biochemical parameters is presented in Table 7. There were no significant differences ($p>0.05$) in serum total protein and its fractions (albumin and globulin) in all experimental groups. However, there were significant differences ($p<0.05$) in cholesterol and triglyceride concentrations between the experimental groups and control. Cholesterol and triglyceride concentrations values were lowest in the MOLM groups compared with the control group.

Discussion

The highest values of final body weight and total body weight gain in the group fed 4% MOLM compared to the other experimental groups may be due to the highest antioxidant content and high nutritional value of MOLM (Karthivashan *et al*., 2013), as it is rich source of protein (Kakengi *et al*., 2007), its effects on improving protein absorption (Lu *et al*., 2016) or its effects as an antibiotic (Ologhobo *et al*., 2014). Furthermore, Onu and Aniebo (2011) found that the presence of essential nutrients and minerals in moringa leaves implies that they can be used to improve growth performance and health status of poultry. However, the poorest body weight and weight gain were recorded in birds fed 8% MOLM in their diet.

Body weight and weight gain were significantly improved ($P<0.05$) with dietary supplementation of MOLM up to 6%. Improvements in body weight and weight gain were noticed by Alikwe *et al*. (2016) who reported that the body weight increased when 6% of MOLM was included in the diets of layers. Also, Abhishek *et al*. (2017) concluded that the overall performance of Vanaraja chickens improved significantly with diets supplemented with 5% MOLM. Mahmud *et al*. (2016) reported that feeding diets contatining 5% MOLM to growing Japanese quails improved the performance efficiency. As well as, Abd-El-Samee *et al*. (2019) determined that 1% and 2% MOLM improved the body weight and weight gain of ducks compared to control group (0% MOLM). On contrary, Onunkwo and George (2015) recorded that there were no significant differences in body weight and weight gain of broilers between the experimental groups and the control group. Additionally, Zhai *et al*. (2020) found that there were no effect of MOLM on body weight and gain of geese. Furthermore, Ibrahim *et al*. (2017) showed that the final body weight and the daily weight gain of ducks decreased as the *Moringa Oleifera* leaves

Table 5. Chemical composition (%) of duck meat during the experiment

Parameters	T1	T2	T3	T4	T5
Breast meat					
DM	25.81 ± 0.35^{b}	27.88 ± 0.34^{ab}	28.08 ± 0.12^{a}	25.07 ± 0.17^{bc}	24.74 ± 0.20^{c}
CP	81.47 ± 0.59^{bc}	83.60 ± 0.21^{ab}	84.37 ± 0.35^{a}	82.60 ± 0.32^{b}	81.32 ± 0.54^{c}
EE	15.67 ± 0.38^{a}	14.40 ± 0.10^{c}	14.80 ± 0.44^{bc}	15.13 ± 0.10^{b}	15.28 ± 0.66^{ab}
Ash	4.87±0.23	4.60±0.21	4.83±0.89	4.76±0.23	5.17±0.13
Thigh meat					
DM	24.30 ± 0.27^{c}	24.70 ± 0.42^{b}	25.50 ± 0.64^{ab}	25.70 ± 0.24^{a}	24.53 ± 0.28^{bc}
CP	79.87 ± 0.17^{bc}	82.30 ± 0.21^{ab}	83.8 ± 0.27^{a}	80.76 ± 0.34^{b}	79.23 ± 0.20^{c}
EE	15.90 ± 0.47^{a}	14.77 ± 0.26^{bc}	13.97 ± 0.30^{c}	15.17 ± 0.09^{b}	15.20 ± 0.26^{ab}
Ash	4.23 ±0.23	4.93 ±0.27	4.20 ±0.15	4.10 ± 0.26	4.57±0.09

T1: control group fed basal diet without any supplementation; T2: 2% MOLM; T3: 4% MOLM; T4: 6% MOLM; T5: 8% MOLM.
*Means within the same raw with different superscripts are significantly different ($P<0.05$).

Table 6. Hematological traits of ducks during the experiment.

Parameters	T1	T2	T3	T4	T5
WBCs ($x10^3/\mu L$)	116.83 ± 1.57^{c}	134.53 ± 4.42^{b}	142.00 ± 2.46^{a}	140.37 ± 4.40^{ab}	124.17 ± 6.77^{bc}
Lymphocyte ($x10^3/\mu L$)	105.60 ± 1.57^{c}	122.67 ± 2.55^{b}	131.67 ± 1.42^{a}	129.67 ± 2.54^{ab}	115.87 ± 3.91^{bc}
Lymphocyte (%)	91.83±0.70	92.63±2.96	94.40±2.38	92.97±3.49	92.60±3.08
Hb (g/d)	18.40±0.25	18.07±2.98	20.73±0.41	21.27±0.60	20.60±1.23
MCH (pg)	85.73±0.29	84.57±0.62	90.47±4.15	91.37±4.11	87.97±1.86
MCHC (g/dl)	57.23 ± 0.33^{c}	57.63 ± 0.43^{bc}	63.37 ± 1.01^{ab}	62.77 ± 1.28^{b}	85.80 ± 1.36^{a}
RBCs ($x10^6/\mu L$)	2.39±0.36	2.56±0.23	2.44±0.32	2.19±0.08	2.31±0.18
MCV (fL)	149.97±0.88	147.97±2.02	146.90±1.40	147.10±1.94	148.10±1.40
HCT (%)	33.00±0.50	35.83±1.20	32.57±1.31	31.96±0.91	36.87±1.21
Plt ($x10^3/\mu L$)	3.67 ± 0.33^{b}	5.33 ± 0.33^{ab}	7.33 ± 0.67^{a}	7.33 ± 0.67^{a}	4.00 ± 0.58^{b}

T1: control group fed basal diet without any supplementation; T2: 2% MOLM; T3: 4% MOLM; T4: 6% MOLM; T5: 8% MOLM.
*Means within the same raw with different superscripts are significantly different ($P<0.05$).

Table 7. Serum biochemical parameters of ducks during the experiment.

Items	T1	T2	T3	T4	T5
Total protein (g/dl)	3.04±0.05	3.10±0.06	3.27±1.56	3.59±0.05	3.90±0.39
Albumin (g/dl)	0.94±0.40	0.94±0.18	0.94±0.06	1.00±0.04	0.80±0.04
Globulin (g/dl)	2.01±0.45	2.16±0.24	2.33±0.41	2.59±0.32	3.10±0.39
Alb/Glob	0.45±0.31	0.44±0.14	0.40±0.08	0.39±0.04	0.26±0.04
Cholesterol (mmol/L)	188.50 ± 1.61^{a}	176.36 ± 1.98^{ab}	172.24 ± 3.29^{b}	141.29 ± 1.68^{bc}	138.30 ± 2.17^{c}
Triglycerides (mmol/L)	185.07 ± 2.29^{a}	129.82 ± 3.51^{bc}	128.17 ± 1.62^{c}	170.95 ± 4.08^{ab}	166.56 ± 4.97^{b}

T1: control group fed basal diet without any supplementation; T2: 2% MOLM; T3: 4% MOLM; T4: 6% MOLM; T5: 8% MOLM.
*Means within the same raw with different superscripts are significantly different ($P<0.05$).

increased. However, reduction in body weight and weight gain of ducks fed 8% MOLM was is not consistent with the results of Egu (2019) who reported that broiler chickens fed 8% MOLM had higher final body weight and weight gain.

Inclusion of 4% of MOLM in duck diets resulted in a significant improvement in their relative growth rate (RGR) compared to other tested groups. This improvement was due to improved body weight gain in the 4% MOLM group. This result is consistent with Onu and Aniebo (2011) who showed that the birds fed MOLM at 2.5% and 5% had the highest weight gain compared to the control.

Feeding of different levels of MOLM to ducklings had no significant effect on feed consumption. This result is consistent with the results of Zanu *et al*. (2012) and Khan *et al*. (2017) who reported that the use of MOLM did not effect on feed consumption of broilers. Additionally, Zhai *et al*. (2020) confirmed that MOLM did not affect the feed consumption of geese. In contrast, Ashmawy and Ibrahim (2019) reported that feed consumption of ducklings decreased in the MOLM groups compared to control group. Numerically higher feed consumption was recorded in ducks fed 4% MOLM supplement in their diets compared to other MOLM groups. This increase in feed consumption is quantitatively related to the high fiber content of *Moringa Oleifera* leaf powder, which tends to increase the total fiber content of the diet and dilute other nutrients. Furthermore, the higher feed consumption in this group may be due to faster fecal transit due to high fiber content as reported by Abhishek *et al*. (2017). On the other hand, ducks fed 8% MOLM recorded lower feed consumption numerically due to reduced diet palatability and it was observed that unpalatable feed prevented chicks from consuming adequate amounts of the feed (Kakengi *et al*., 2007). The result was is consistent with the results of Onu and Aniebo (2011) who found significant differences in broilers feed intake between experimental groups. Feed consumption has increased significantly with increasing levels of MOLM inclusion. However, there was a significant reduction in feed consumption in birds fed 7. 5% MOLM in their diets.

In our study, the best feed conversion values were observed in the group fed with a diet containing 4% MOLM compared to the other tested and control groups. This improvement in FCR may be attributed to the highest body weight gain and feed consumprtion in the group fed 4% MOLM compared to the other experimental groups. These results are consistent with the results of Yang *et al*. (2020) who showed that the best feed conversion ratio was recorded in ducks fed 4% MOLM. In contarst, Khan *et al*. (2017) found that FCR is not affected by supplementation of MOLM in the broiler diets. Additionally, Divya *et al*. (2014) observed that there was no significant change in feed conversion ratio of broilers fed different dietary four levels of Moringa leaf powder (0.5%, 1.0%, 1.5% and 2.0%).

The highest value of performance index (PI) was found in the group fed diets contatining 4% MOLM. These results disagree with Mahmud *et al*. (2016) who reported that there was a statistically significant difference in the mean PI of growing Japanese quails in the four treatments (0, 5, 10 and 15% MOLM). The PI of the control group was significantly highest among all treatment groups, while the PI of the group fed 10% MOLM was ignificantly lowest among the four treatment groups.

Numerically, the lowest value of crude protein intake (CPI) was recorded by group fed 8% MOLM, while the highest value of CPI was recorded by group fed 4% MOLM. These inconformity with Onu and Aniebo (2011) who found that protein intake of broilers fed on MOLM significantly higher than that of control, but the various dietary groups didn't produce significant differences in protein efficiency ratio (PER). Also this results disagreed with Mahmud *et al*. (2016) who recorded that the PER of control group had the higher value compared to all treated groups fed on MOLM.

Data on metabolizable energy intake and caloric efficiency ratio of ducks showed no significant ($P>0.05$) differences in metabolizable energy intake and caloric efficiency ratio between control and experimental groups. In general, many researchers believe that, *M. Oleifera* plant can play an important role in improving the production performance and health status of ducks. However, further studies are are needed to determine the appropriate dosage to achieve ideal performance in ducks.

Pre-slaughter weight, eviscerated weight and dressing weight were increased significantly ($P<0.05$) in T2, T3, T4 groups fed 2%, 4% and 6% MOLM compared to the groups fed 8% MOLM and control diets. This means that MOLM improved carcass yield and dressing weight up to 6% and this improvement may be attributed to the improvement in final body weight of birds fed MOLM in diets. This may also be due to the improved digestibility of the feed ingredients in MOLM supplements. The reduction in pre-slaughter weight, eviscerated and dressing weights in T5 group fed diets containing 8% MOLM diets was likely due to the effect of increased fiber content in the higher MOLM inclusion diets. The improvements in eviscerated and dressing weights were in consistent with David *et al*. (2012) who reported that MOLM supplementation increased live weight, post-bleed weight, weight after defeathering and dressing percentage of broiler chickens compared to the control (0% MOLM). Additionally, El-Tazi (2012) found that birds fed on diets supplemented with MOLM (3%, 5% and 7%) had significantly heavier hot and cold eviscerated carcass weights and dressing percentage than control group. On contrary, Ologhobo *et al*. (2014) showed that inclusion of Moringa leaf meal had no adverse effect on dressing percentage. Abhishek *et al*. (2017) found that carcass characteristics were significantly affected in groups fed diet containing MOLM, while relative weight of liver and spleen was significantly reduced with increased dietary level of MOLM in the ration of Vanaraja chicken as compared to control group. However, dressing percentage was not much influenced with treatment groups. As well as, Ibrahim *et al*. (2017) reported that the dressing weight and percentage decreased with increasing MOLM in diets of ducks. Additionally, Zhai *et al*. (2020) reported that there were no significant differences in carcass characteristic of geese between experimental groups fed MOLM and control group.

Differences in results between the previous studies may be due to the differences in the inclusion level of MOLM or the plant part used (leaves, seeds, extract, etc.). There were no significant differences in the relative weights of heart, liver, spleen and gizzard of ducks fed diet supplemented with MOLM compared to the control group. From these results it can be inferred that the use of MOLM in duck diets does not affect on the organ proportion of ducks. There were significant differences between the different experimental groups in the relative weight of the proventriculus. These results are consistent with those of Ayo-Ajasa *et al*. (2016) who found that the incorporation of MOLM in the diets of broilers had no significant effect on relative organs weights. Mahmud *et al*. (2016) recorded that the average weight of spleen, breast, thigh, drumstick, wing and liver of the growing Japanese quails were not significantly different when using MOLM to partially replace of soyabean meal. Additionally, Zhai *et al*. (2020) showed no significant effect on total organs weights (except gizzard) in experimental group fed 0, 20, 40, 60, 80 or 100 g/kg MOLM in geese diet. On the other hand, Onunkwo and George (2015) reported that there was a significant difference in the organs weights (liver and gizzard) of broilers between experimental groups fed diets conataining MOLM and control, while group fed diets containing 10 % MOLM had the highest value of thigh, shank, liver and spleen. Additionally, Ibrahim *et al*. (2017) recorded a significant increase in liver and gizzard weights of ducks fed diets supplemented with 2% MOLM. However, Abd-El-Samee *et al*. (2019) reported that the highest percentage of heart, liver and gizzard were recorded in ducks fed a MOLM-enriched diet compared to the control group.

Regarding the influence of dietary MOLM levels on the chemical composition of carcasses, the obtained results showed that MOLM supplementation significantly increased ($P<0.05$) DM, CP and EE of breast meat compared to control group. DM content was higher in the T3 MOLM group (28.08) than in the control group (25.81). The CP of the breast meat in the groups fed diets conataining 2 and 4% MOLM was higher (83.60 and 84.37, respectively) than groups fed diets supplemented with 6% and 8% MOLM and control group (82.60, 81.32 and 81.47, respectively). There was a significant reduction in EE levels in the breast meat when diets were supplemented with MOLM. Supplementation of MOLM increased the DM, CP and EE contents of thigh meat ($P< 0.05$), while ash content was not affected. The CP content of thigh muscles in T3 group (4% MOLM) was higher than in other groups. In contrast, the content of EE in thigh meat was lowest in T3 group (4% MOLM). The explanation for increase in DM could be due to the increased protein content of the experimental duck meat. Additionally, the high protein content in the meat of ducks fed MOLM may be due to the role of *M. Oleifera* in increasing protein absorption and protein retention. These results correspond to those of Zanu *et al*. (2012) who reported that crude protein content in meat increased and fat content decreased with increasing MOLM in broiler diets. In contrast, Abhishek *et al*. (2017) found that the fat content of chicken meat decreased significantly with increasing levels of MOLM supplementation (5, 10, 15 and 20%) in chickens diets, while total ash content increased with high MOLM levels than control group, while crude protein content is not much affected by treatment. Furthermore, Abd-El-Samee *et al*. (2019) recorded significant differences in Ash and lipids values in the meat of ducks fed diets supplemented with 1% and 2% MOLM. However, MOLM has a negligible effect on meat moisture and protein (%). Similarly, Tesfaye *et al*. (2013) reported that the moisture, Ash, CP and EE in the breast and thigh muscles of broilers were not affected by the inclusion of MOLM in the diet, except that the CP content in the thigh muscle was higher at 15% than 5% and 20% of MOLM.

The results of hematological picture of ducks showed that T2, T3 and T4 groups had the highest numbers of WBCs and platelets. Although MOLM claims to strengthen the immune system. The main function of phagocytes is to defend against invading microorganisms by ingesting and destroying them, thereby contributing to cellular inflammato-

ry processes, was reinforced (Adedapo *et al*., 2009), which may explain its antibacterial activity (Fahey, 2005). Thus improving the health status of the experimental birds, consistent with Du *et al*. (2007) who reported that dietary supplementation with *M. Oleifera* can increase the immunity of broilers. However, these results disagree with Ashmawy and Ibrahim (2019) who found that MOLM had no effect on WBCs count and platelets of ducks fed on *Moringa Oleifera* leaves meal (MOLM). Similarly, Onu and Aniebo (2011) and Zanu *et al*. (2012) found no significant differences in all hematological parameters, except MCH, when *Moringa Oleifera* leaf meal was used in broiler diets.

Regarding serum biochemical parameters, there were no significant differences (P>0.05) in serum total protein and its fractions in all experimental groups. These results are similar to those of Zanu *et al*. (2012) and Ahemen *et al*. (2013) who found that there was no significant difference in serum total protein and its fractions (albumin and globulin) of birds fed an experimental diets containing MOLM. Ibrahim *et al*. (2017) illustrated that supplementation of 1% MOLM in the diets of Mulard ducks promoted serum total protein compared to the control group, while supplementation of 2% MOLM had a lowering effect on blood protein which may be due to the toxic substances present in MOLM in relatively higher concentrations. In contrast, Hassan *et al*. (2016) recorded that plasma total protein levels increased significantly as MOLM increased in broiler diets, the highest levels were recorded in groups fed diets containing 0.2 and 0.3% MOLM. Additionally, Kasiyati *et al*. (2019) found that serum protein concentrations in experimental ducks supplemented with MOLM increased compared to ducks in control group.

Cholesterol concentration was lowest in T5 group (8% MOLM) but triglyceride concentration was lowest in T3 group (4% MOLM). This result indicates that the polyphenols content in MOLM can inhibit the absorption of lipid and cholesterol through the digestive tract or increase the liver's ability to eliminate cholesterol (Kasiyati *et al*., 2019). These results are consistent with the results of Ashong and Brown (2011) who reported that the control group had significantly higher cholesterol and triglyceride levels in broilers. Zanu *et al*., (2012) also showed that the cholesterol and triglyceride concentrations of the broilers fed diets containing 5% MOLM were the lowest values. Furthermore, Egu (2019) reported that serum cholesterol content in birds fed a control diet was significantly higher than in birds fed 6%, 8% and 10% MOLM. The present results are not agree with the results of Ahemen *et al*. (2013) who showed no significant differences in cholesterol level between rabbits fed diets containing different levels of MOLM.

Conclusion

The addition of 4% *Moringa Oleifera* meal (MOLM) to the diets of Mulard ducklings had beneficial effects on the growth performance parameters, meat composition and carcass characteristics. Dietary inclusion of *Moringa Oleifera* meal to duck diets reduced serum triglycerides and cholesterol concentrations and improved the immunity by increasing the number of white blood cells and lymphocytes. Therefore, it is recommended that *Moringa Oleifera* meal can be used as a good supplement in duck production.

Conflict of interest

The authors declare that they have no conflict of interests.

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