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Performance of Koekoek Chicken Fed with Different Levels of *Moringa oleifera* Leaf Meal

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Abstract

This study was carried out to assess the feeding value of *Moringa oleifera* leaf meal (MOLM) in layers ration on feed intake, body weight (BW) change, feed conversion ratio, egg quality and shelf life. A total of 96 Koekoek hens aging 41 weeks were used and equally divided into 4 dietary treatments with a completely randomized design (CRD). Treatments are rations contained MOLM at the level of 0% (T_1), 5% (T_2), 10% (T_3) and 15% (T_4) with 3 replications. Body weight (BW) change was calculated by taking the difference of BW taken at start (initial BW) and end of the experiment (final BW). Data on feed intake and egg weight were recorded daily and mortality rate as it occurred throughout the experimental period. Egg quality was evaluated bi-weekly on 4 eggs per replicate. The shelf life of eggs was determined by considering albumen and yolk measurements as well as Haugh unit at an interval of 7 days on 4 eggs per replicate stored for 7, 14, 21 and 28 days. Albumen and yolk pH of eggs stored at 7, 14, 21 and 28 days was also determined to evaluate the shelf life. Parameters considered during the study showed a positive (P<0.05) response. Body weight change was 0.32 kg in T_1, 0.43 kg in T_2, 0.48 kg in T_3 and 0.37 kg in T_4. Feed conversion ratio (FCR (kg egg/kg feed)) was 1.73 in T_1, 2.10 in T_2, 1.52 in T_3 and 1.59 in T_4. BW change were recorded for T_3 while higher yolk color was observed for T_3 and average egg weight was 48.66 gm in T_1, 54.51 gm in T_2, 49.94 gm in T_3 and 50.31 gm in T_4. Higher feed intake and T_4. In the present study, it was possible to prolong the age of eggs from hens that fed 5% MOLM than the control and other treatments. From most parameters considered in this study like feed intake, BW change and FCR; better egg quality and prolonged shelf life for internal egg quality, it is concluded that addition of 5% MOLM in the layers diet is recommended. *Moringa oleifera* leaf meal utilization at 5% in the poultry industry may serve the sector by enhancing the product quality as a feed additive besides serving as protein feed.

Keywords: Body weight change; Feed intake; Egg quality; *Moringa oleifera*

Introduction

Moringa (*Moringa oleifera* L.) is a widespread, multipurpose tree reported to have nutritional, therapeutic and prophylactic properties [1] and has several industrial applications which are derived from its leaves and fruits [2]. *M. oleifera* is commonly referred to as the Horseradish tree, Drumstick tree, Moringa, Mother's best friend, West Indian bean and Bean oil [3]. It is the most widely cultivated species of a monogeneric family, Moringaceae, and includes 13 species of trees and shrubs native and distributed in sub-Himalayan regions of India, Sri-lanka, North Eastern and South Western Africa, Madagascar and Arabia [4]. In Ethiopia the tree is called as 'Shiferaw' or 'Cabbage Tree' and mostly found in the southern region.

M. oleifera is a rapidly growing tree which is easy to establish and cultivate. It is propagated either by planting or by seeding [5]. It also has good coppicing ability after pruning, and a capacity to produce high quantities of fresh biomass up to 120 tones dry matter/ha/year even at high planting densities [6]. *M. oleifera* is drought tolerant and tolerated annual precipitation of 500 to 1500 mm and annual temperatures from 18.7 to 28.5°C. *M. oleifera* is adapted to a wide range of soil types and conditions, neutral to slightly acidic soil (pH range of 5.0 to 6.5) it grows best in sandy soils, sensitive to water logging and frost.

Leaves of *M. oleifera* have a great value of nutrients thus indicated as the plant serve as a potential source of food supplement, used as a protein complement [7]. *M. oleifera*'s antioxidant properties alleviated the effect of stress in goats [2,8] evidenced by lower initial meat pH in goats supplemented with *M. oleifera* leaves compared to the ones fed on grass hay only [9]. The meat color can be modified by dietary antioxidants and minimize rancidity, retard lipid peroxidation, resulting in maintained meat quality and enhanced shelf life [10,11]. *M. oleifera* is endowed with some antioxidant properties [12,13]. Antioxidants are substances that may protect animal cells against the damage caused by free radicals that cause oxidation in the body [14]. Findings by researchers [15,16] indicated that *M. oleifera* leaves contain various phytochemicals:

carotenoids, vitamins, chlorophyll, xanthins, minerals, amino acids, sterols, cytokines, alkaloids, flavonoids and phenolics. The presence of such phytochemicals might make *M. oleifera* a potential antioxidant. Administration of *M. oleifera* extract decreased hepatic marker enzymes and lipid peroxidation with simultaneous increase in the level of antioxidants as reported by Ashok and Pari, et al. [17]. Findings supported by Verma et al. [15] that the leaves of *M. oleifera* have phenols which are known to scavenge free radicals. *M. oleifera* leaves contain selenium and zinc [1] which is components of antioxidant enzymes. It is the need of this project to evaluate the importance of *M. oleifera* leaf meal (MOLM) on the quality and shelf life of chicken egg due to the nutritional composition reviewed.

Materials and Methods

Animals, Experimental Design and Treatments

The experiment was conducted at Debre Zeit Agricultural Research Center (DZARC), located 47 km far from southeast of Addis Ababa, Ethiopia. A total of 96 Koekoek 41 weeks old hens were in completely randomized design distributed into 12 pens with 8 hens in each pen and 3 replications.

The chemical compositions of feed ingredients were determined through proximate analysis (Table 1) from which experimental diets were prepared to be nearly isocaloric and isonitrogenous (Table 2), at ME of 2,750 kcal/kg of DM and 16.5% of CP. The hens were randomly assigned to four treatments: 0% MOLM (T_1, control), 5% MOLM (T_2), 10% MOLM (T_3), and 15% MOLM (T_4). Leaf was harvested from *Moringa oleifera* trees from an orchard found in DZARC poultry farm. The harvested leaves from the tree were twigged and spread out on a concrete floor and allowed to dry under shade and aerated conditions then run through a hammer mill with a size of 5 mm to produce the leaf meal.

Experimental pens, laying nests, watering and feeding troughs were thoroughly cleaned, disinfected, and sprayed against external parasites before the onset of the experiment. Birds were fed twice a day (08:00 AM and 17:00 PM) and clean water was available at all times. Diets were offered 130 gm/bird/day in a round feeder and water in a plastic fountain in a deep litter house covered with *Tef* straw. Fluorescent lamps of 20 lux were used for the lighting purpose for 4 hours; and 12 hours natural light. Before the commencement of the actual data collection, birds were adapted to respective treatment diet for a week.

Table 1: Chemical composition of ingredients.

Ingredients	Corn grain	Wheat middling	Soybean meal	Nougseed cake	MOLM[6]
[1]DM (%)	91.8	92.1	93.8	91.6	86.9
[2]CP (%DM)	8.32	16.3	40.8	33.8	29.2
[3]CF (%DM)	3.6	8.9	6.9	18.1	10.5
[4]EE (%DM)	4.3	5.0	6.3	7.3	5.6
Ash (%DM)	3.4	3.9	6.1	10.5	12.9
[5]ME (Kcal/kg DM)	3270	2038	2498	2230	2247
Calcium (%DM)	0.06	0.12	0.30	0.28	2.76
Phosphorus (%DM)	0.33	1.12	0.68	0.67	0.35
Beta carotene (mg/100g)	-	-	-	-	15.60

[1]Dry Matter, [2]Crude Proteins, [3]Crude Fibers, [4]Ether Extract, [5]Metabolizable Energy, [6]*Moringa Oleifera* Leaf Meal.

Table 2: Proportion (%) of ingredients used for formulating experimental diets.

Ingredient (%)	Treatment			
	T_1	T_2	T_3	T_4
Corn grain	60.00	60.00	60.00	59.00
Wheat middling	6.30	3.80	2.80	2.00
Nougseed cake	4.50	5.00	5.00	3.80
SBM	21.00	18.00	14.00	12.00
MOLM	0.00	5.00	10.00	15.00
Vitamin premix	0.50	0.50	0.50	0.50
Salt	0.30	0.30	0.30	0.30
Limestone	7.00	7.00	7.00	7.00
Methionine	0.10	0.10	0.10	0.10
Lysine	0.30	0.30	0.30	0.30
Total %	**100**	**100**	**100**	**100**
CP %	16.12	16.10	15.77	15.80
ME (kcal/kg DM)	2714	2711	2704	2691
DM %	90.68	89.76	89.60	89.48
Ash (% DM)	8.93	9.20	10.90	10.97
EE (% DM)	6.55	7.14	7.26	7.34
CF (% DM)	6.14	7.05	7.20	7.26

MOLM: *Moringa Oleifera* Leaf Meal; SBM: Soybean Meal; T_1: No MOLM Inclusion; T_2: 5%; T_3: 10%; T_4: 15% MOLM of the Total Ration Substituting SBM; CP: Crude Protein; DM: Dry Matter, EE: Ether Extract, CF: Crude Fibre.

Measurements

The experimental period lasted for 12 weeks during which the amount of feed offered to and refused from birds per pen was recorded daily and feed consumption calculated from the difference. At the start and end of the experiment hens were weighed and body weight (BW) change was calculated as the difference between the final and initial BW. Feed conversion ratio was determined as a unit egg weight per unit feed consumed. Mortality was recorded as it occurred.

Egg quality parameters were assessed at the middle and end of the experiment in terms of egg weight and shape index externally and the internal egg quality parameters were assessed by breaking eggs on a flat glass and separating each of the components such as shell weight, shell thickness, yolk color, yolk weight, yolk length, yolk height, yolk index, albumen weight, albumen height and Haugh unit. The shell, albumen and yolk were carefully separated and weighed individually. Shell weight and thickness were taken by removing the internal membrane. Shell thickness was measured as the average of the broad, middle and sharp points of the egg by using a digital micrometer. Albumen and yolk height were measured by tripod micrometer. Haugh unit (HU) was calculated using the formula (100 log10 (h+7.57−1.7w0.37, [18]: where; h=observed albumen height (mm), w=weight of egg (g). Yolk color was determined by Roche color fan measurement. Digital caliper was used to measure the length and width of the egg and the length of yolk, shape indexes were computed accordingly [19]

Egg shape index=width of egg/length of egg × 100

Yolk index=yolk height/yolk length

For the measurement of egg shelf life, eggs were stored for 1, 2, 3 and 4 weeks at room temperature, 12 eggs per treatment were randomly taken and albumen and yolk measurements were taken and their pH by using pH meter twice during the experimental period at the middle and end of the experiment [20].

Statistical analysis

Data were analyzed using the general linear model procedures of Statistical Analysis Systems software with the model containing treatments. One way ANOVA was employed. Differences between treatment means were separated using Tukey Kramer test [21].

Results

Feed consumption, body weight and feed conversion ratio

The effect of inclusion of MOLM at different levels on feed intake, BW change and FCR of dual purpose Koekeok hens is presented in table 3. Total feed intake was higher (P ≤ 0.05) for hens in T_1 and T_3 as compared to the others with the lowest intake recorded for T_2. However, the final BW was highest (P<0.05) for hens in T_2 than hens in T_4 and T_1 but statistically the same with that of T_3. Similarly, hens fed 5% MOLM (T_2) had higher (P<0.05) BW change than hens in T_3 and T_4 but not significantly differ (P>0.05) with T_1. The FCR (kg egg/kg feed) was higher (P<0.05) for T_2 than the rest of the treatments, with no differences (P>0.05) between the other treatments.

Egg Quality

Results of egg quality parameters are presented in table 4. Egg length was higher for T_2 (P<0.05) than the others and was in the

Table 3: Feed intake, body weight change and feed conversion ratio of dual purpose Koekoek hens fed different levels of MOLM for 12 weeks.

Parameters	Treatments (Means ± SEM)				
	T_1	T_2	T_3	T_4	Sig.
TFI (kg)	10.73 ± 0.01^a	10.16 ± 0.04^c	10.73 ± 0.07^a	10.37 ± 0.01^b	*
IBW (kg)	1.54 ± 0.02^a	1.54 ± 0.02^a	1.54 ± 0.01^a	1.54 ± 0.01^a	NS
FBW (kg)	1.86 ± 0.01^b	1.93 ± 0.02^a	1.90 ± 0.01^{ab}	1.77 ± 0.01^c	*
BWC (kg)	0.32 ± 0.02^{ab}	0.38 ± 0.01^a	0.35 ± 0.01^b	0.22 ± 0.02^c	*
FCR (kg egg/kg feed)	1.73 ± 0.0^{4}b	2.10 ± 0.03^a	1.52 ± 0.01^b	1.59 ± 0.10^b	*

*: P<0.05; Means followed by the same letter in rows do not differ statistically from one another by the Tukey test at 5% probability; MOLM: *Moringa oleifera* Leaf Meal; SBM: Soybean meal; T1: Ration containing 0% MOLM; T_2: Ration containing 5% MOLM; T_3: Ration containing 10% MOLM; T_4: Ration containing 15% MOLM; NS: Non-significant; TFI: Total Feed Intake; IABW: Initial Average Body Weight; FABW: Final Average Body Weight; BWC: Body Weight Change; FCR: Feed Conversion Ratio.

Table 4: Effects of feeding different levels of MOLM as a substitute for SBM on egg quality parameters of dual purpose Koekoek hens.

Parameters	Treatments				
	T_1	T_2	T_3	T_4	Sig.
Egg shape index	80.92 ± 0.56^a	75.80 ± 0.10^c	77.23 ± 0.76^{bc}	78.79 ± 0.25^{ab}	*
Egg weight (g)	48.66 ± 0.36^b	54.51 ± 0.47^a	49.94 ± 0.91^b	50.31 ± 0.33^b	*
AST (mm)	0.29 ± 0.003^b	0.38 ± 0.003^a	0.31 ± 0.01^b	0.30 ± 0.01^b	*
Shell weight (g)	5.67 ± 0.33^b	8.66 ± 0.33^a	6.33 ± 0.66^b	6.00 ± 0.57^b	*
AH(mm)	5.33 ± 0.33^b	7.33 ± 0.33^a	5.66 ± 0.33^{ab}	7.00 ± 0.57^{ab}	*
AW (g)	21.67 ± 0.33^c	29.66 ± 1.20^a	25.33 ± 0.33^b	23.33 ± 0.88^{cb}	*
Haugh unit	75.33 ± 0.33^b	87.33 ± 0.33^a	79.00 ± 0.57^b	77.67 ± 1.45^b	*
Yolk weight (g)	15.33 ± 0.33^b	20.66 ± 0.33^a	17.00 ± 1.00^b	17.33 ± 0.33^b	*
Yolk color	1.00 ± 0.00^c	8.66 ± 0.33^b	11.33 ± 0.33^a	11.33 ± 0.33^a	*
Yolk index	0.27 ± 0.57^b	0.34 ± 0.33^a	0.33 ± 0.57^{ab}	0.32 ± 0.33^{ab}	*

*: P<0.05; Means followed by same letter in rows do not differ statistically from one another by the Tukey test at 5% probability. MOLM: *M. oleifera* leaf meal; SBM: Soybean meal; T: Ration containing 0% MOLM; T_2: Ration containing 5% MOLM; T_3: Ration containing 10% MOLM; T_4: Ration containing 15% MOLM; AST: Average Shell Thickness; AH: Albumen Height; AW: Albumen Weight; YL: Yolk Length; YH: Yolk Height.

order of $T_2>T_3>T_4>T_1$. Egg width was also higher (P<0.05) in T_2 than T_1, T_3 and T_4. Hens in T_3 and T_4 had higher (P>0.05) egg width than hens in T_1. Significantly higher (P<0.05) egg shape index was observed in T_1 than in T_2 and T_3 with no differences between T_2 and T_3, and T_3 and T_4, but hens in T_2 had less egg shape index than T_1 and T_4. Egg weight was higher (P<0.05) in T_2 than T_1, T_3 and T_4; T_2 also had higher (P<0.05) egg shell weight and thickness than the others; T_1, T_3 and T_4 had no significant difference between each. Albumen height was higher (P<0.05) for T_2 than T_1, but was the same (P>0.05) with that of the rest of the treatments. Albumen weight was higher (P<0.05) for T_2 than all the remaining treatments. Consequently, Haugh unit was also higher (P<0.05) in T_2 than the rest of the treatments.

Similarly, T_2 had higher (P<0.05) yolk weight than the rest of the treatments. Yolk color was higher (P<0.05) with the same value for T_3 and T_4 than that of T_1 and T_2. Hens in the control diet had the poorest yolk color than the rest of the treatments. Yolk length was highest (P<0.05) for T_2 than that of hens in the rest of the treatments. Hens in T_1 had the lowest yolk length as compared to that for T_3 and T_4, which had similar yolk length. Yolk height was the least for T_1 than the rest of the treatments, which had similar yolk height. Hens in T_2 had higher yolk index (P<0.05) than hens in T_1, but yolk index did not vary between T_2, T_3 and T_4; however, similar yolk index was observed between the control and T_3 and T_4.

Egg shelf life

Yolk and albumen pH: The effect of feeding different levels of dietary MOLM on yolk and albumen pH of eggs of dual purpose Koekoek hens is shown in table 5. The results revealed that the yolk pH of eggs stored for a week was the lowest (P<0.05) for T_2 than the rest of the treatments. Although T_1 and T_3 had similar yolk pH at 7 days of storage, but their yolk pH was lower than T_4. Also, the yolk pH of eggs stored for 2 weeks was the lowest (P<0.05) for T_2 than the rest of the treatments, but all other treatments had similar yolk pH. In the same way, the yolk pH of eggs stored for 3 weeks was lower (P<0.05) for T_2 than for T_4. But T_1 and T_3 were not significantly differing with T_4. The pH of eggs stored for 4 weeks was the lowest for T_2 than eggs in the rest of the treatments, but eggs in T_1 had higher (P<0.05) pH than eggs in T_3, which had no significant difference with pH of eggs in T_4.

At 7 days of storage, T_2 had lower mean albumen pH than T_4 but statistically not different (P>0.05) with T_1 and T_3. At 2 weeks of storage, T_1 and T_4 had higher (P<0.05) albumen pH than T_2 and T_3. Lower albumen pH was recorded for eggs from hens fed 5% MOLM (T_2) than the others. Similar trend was also observed on albumen pH that stored for 3 weeks of eggs obtained from hens that fed treatment diets. Higher (P<0.05) albumen pH was observed in T_1 and T_4 than T_2 and T_3 with no significant difference (P>0.05) between T_1 and T_4. At 4 weeks of egg storage, lower mean value (P<0.05) was recorded in T_2 and there was no significant difference (P>0.05) observed among the others.

Albumen and yolk measurements: The effect of MOLM on yolk and albumen measurements at different storage times is summarized in table 6. The results indicated that different levels of dietary treatment of MOLM had significant effect on those parameters regarding with storage time. At 1 weeks of storage, higher (P<0.05) albumen height was recorded in T_2 than T_1 and T_3 but was not significantly different (P>0.05) with T_4. At 2 weeks of storage, T_2 showed a higher value than the others with no statistical difference (P>0.05) between T_3 and T_4, and T_3 and T_1. At 3 weeks of eggs storage from hens fed the treatment diets, higher value (P<0.05) of albumen height was recorded in T_2 than the rest. Besides, at 4 weeks of storage, lower value (P<0.05) of albumen height was observed in T_1 than the others but did not vary with T_4. It was observed that T_2 had a higher (P<0.05) albumen height than the rest of the treatments. Haugh unit calculated was affected by higher mean value of albumen height obtained in T_2. A higher and similar trend obtained in all the storage periods and it was significantly different (P<0.05) with the others. The trend in albumen weight was also similar as to the Haugh unit and albumen height in all the storage periods considered. It was revealed a higher (P<0.05) value in eggs obtained from birds fed 5% MOLM (T_2) than others. The albumen weight in T_1, T_3 and T_4 at a week of storage was not significantly (P>0.05) different.

Effect of MOLM on egg shelf life in terms of yolk measurements at different storage times was presented in table 7. In all the periods (1, 2, 3 and 4 weeks of egg storage) the trend was similar and it observed a higher yolk weight in T_2 in the order of $T_2>T_3>T_1=T_4$. At a week of storage, higher yolk length was observed in T_2 while lower in T_1 than T_3 and T_4. There was significant difference (P<0.05) among the treatments. At 2 weeks of storage, higher (P<0.05) mean value in yolk length was recorded in T_2 and lower in T_1 than the others. There was no difference (P>0.05) between T_3 and T_4. Likewise, the same happen at 3 weeks of storage. A higher value in yolk length was obtained in T_2 and lower in T_1 than the others at 4 weeks of storage also with a significant (P<0.05) difference among the treatments. Lower yolk height was obtained in T_1 than the others but it had no significant difference with T_4. Eggs in T_2 had higher mean yolk height (P<0.05) than T_1 but was not different between T_3 and T_4 at a week of storage. There was also no significant difference (P>0.05) between T_3 and T_4. At 2 weeks of storage, higher yolk height was obtained in T_2 and lower one was in T_1 which was lower (P<0.05) than T_3 and T_4 with non-significant difference between T_3 and T_4. Similarly, at 3 weeks of storage, T_2 had higher value than all the treatments and T_1 had lower mean value (P<0.05) than T_3 and T_4; there was no difference (P>0.05) between T_3 and T_4. At 4 weeks of storage, T_2 had higher yolk height (P<0.05) than the others and lower value was obtained in T_1 but was not variable (P>0.05) with T_4; there was no significant difference (P>0.05) between T_3 and T_4.

Table 5: Effects of MOLM on egg shelf life of dual purpose Koekeok hens in terms of yolk and albumen pH at 1, 2, 3 and 4 weeks of storage time.

Parameters	Treatments				
	T_1	T_2	T_3	T_4	Sig.
Yolk pH, EST(d)					
7	6.32 ± 0.05[b]	6.15 ± 0.01[c]	6.39 ± 0.03[b]	6.55 ± 0.02[a]	*
14	6.52 ± 0.09[a]	6.23 ± 0.01[b]	6.51 ± 0.01[a]	6.66 ± 0.008[a]	*
21	6.61 ± 0.13[ab]	6.29 ± 0.02[b]	6.61 ± 0.05[ab]	6.76 ± 0.01[a]	*
28	7.05 ± 0.10[a]	6.51 ± 0.01[c]	6.81 ± 0.02[b]	6.97 ± 0.02[ab]	*
Albumen pH, EST(d)					
7	8.34 ± 0.08[ab]	8.18 ± 0.02[b]	8.32 ± 0.03[ab]	8.66 ± 0.18[a]	*
14	8.78 ± 0.06[a]	8.21 ± 0.02[c]	8.44 ± 0.01[b]	8.75 ± 0.003[a]	*
21	8.92 ± 0.01[a]	8.24 ± 0.008[c]	8.58 ± 0.02[b]	8.86 ± 0.03[a]	*
28	8.97 ± 0.05[a]	8.30 ± 0.04[b]	8.83 ± 0.01[a]	8.94 ± 0.008[a]	*

*: P<0.05; Means followed by the same letter in rows do not differ statistically from one another by the Tukey test at 5% probability. MOLM: *Moringa oleifera* Leaf Meal; SBM: Soybean meal. T_1: Ration containing 0% MOLM; T_2: Ration containing 5% MOLM; T_3: Ration containing 10% MOLM; T_4: Ration containing 15% MOLM; EST: Egg Storage Time; d: Days.

Table 6: Effects of MOLM on egg shelf life of dual purpose Koekoek hens in terms of albumen and Haugh measurements at different storage times (1, 2, 3 and 4 weeks).

Parameters	Treatments				
	T_1	T_2	T_3	T_4	Sig.
Albumen height, EST(d)					
7	6.00 ± 0.00[b]	8.00 ± 0.00[a]	6.00 ± 0.00[b]	7.00 ± 1.00[a]	*
14	4.66 ± 0.33[c]	8.00 ± 0.00[a]	5.33 ± 0.33[cb]	6.00 ± 0.00[b]	*
21	4.33 ± 0.33[b]	7.00 ± 0.00[a]	5.00 ± 0.00[b]	5.00 ± 0.00[b]	*
28	4.00 ± 0.00[c]	6.66 ± 0.33[a]	5.33 ± 0.33[b]	4.33 ± 0.33[cb]	*
Haugh unit, EST(d)					
7	80.00 ± 0.00[b]	87.33 ± 0.33[a]	80.33 ± 0.33[b]	79.67 ± 0.33[b]	*
14	74.33 ± 0.33[c]	87.33 ± 0.33[a]	80.00 ± 0.57[b]	78.66 ± 0.33[b]	*
21	71.66 ± 0.33[c]	85.66 ± 0.33[a]	78.66 ± 0.33[b]	77.00 ± 0.57[b]	*
28	69.00 ± 0.57[c]	85.00 ± 0.57[a]	77.00 ± 0.57[b]	74.66 ± 0.66[b]	*
Albumen weight, EST(d)					
7	22.00 ± 0.00[b]	30.00 ± 1.15[a]	23.00 ± 1.00[b]	23.67 ± 0.88[b]	*
14	18.66 ± 0.33[c]	30.00 ± 1.15[a]	21.00 ± 0.57[cb]	22.33 ± 0.33[b]	*
21	16.00 ± 0.57[c]	28.00 ± 0.57[a]	20.33 ± 0.33[b]	20.33 ± 0.33[b]	*
28	14.33 ± 0.33[c]	26.00 ± 0.57[a]	20.33 ± 0.33[b]	19.66 ± 0.33[b]	*

*: P<0.05; Means followed by the same letter in rows do not differ statistically from one another by the Tukey test at 5% probability; MOLM: *Moringa oleifera* Leaf Meal; SBM: Soybean Meal; T_1: Ration containing 0% MOLM; T_2: Ration containing 5% MOLM; T_3: Ration containing 10% MOLM; T_4: Ration containing 15% MOLM; EST: Egg Storage Time; d: Days.

Table 7: Effects of MOLM on egg shelf life of dual purpose Koekoek hens in terms of yolk measurements at different storage times (1, 2, 3 and 4 weeks of storage).

Parameters	Treatments				Sig.
	T_1	T_2	T_3	T_4	
Yolk weight EST(d)					
7	16.67 ± 0.33[c]	21.66 ± 0.33[a]	19.33 ± 0.33[b]	17.33 ± 0.33[c]	*
14	14.33 ± 0.33[c]	21.66 ± 0.33[a]	18.00 ± 0.57[b]	15.66 ± 0.33[c]	*
21	13.00 ± 0.57[c]	20.00 ± 0.57[a]	17.00 ± 0.57[b]	14.33 ± 0.33[c]	*
28	12.33 ± 0.33[c]	20.00 ± 0.57[a]	15.33 ± 0.33[b]	13.33 ± 0.33[c]	*
Yolk length EST(d)					
7	37.38 ± 0.22[d]	47.50 ± 0.30[a]	42.63 ± 0.26[b]	41.19 ± 0.40[c]	*
14	36.39 ± 0.80[c]	47.50 ± 0.30[a]	41.02 ± 0.31[b]	40.15 ± 0.68[b]	*
21	33.13 ± 0.30[c]	45.42 ± 0.35[a]	40.14 ± 0.33[b]	38.61 ± 0.71[b]	*
28	31.62 ± 0.47[d]	45.42 ± 0.35[a]	38.99 ± 0.36[b]	36.75 ± 0.50[c]	*
Yolk height EST(d)					
7	11.33 ± 0.33[b]	15.66 ± 0.33[a]	14.00 ± 0.57[a]	13.67 ± 0.88[ab]	*
14	10.33 ± 0.33[c]	15.66 ± 0.33[a]	13.33 ± 0.33[b]	13.33 ± 0.33[b]	*
21	9.33 ± 0.33[c]	15.00 ± 0.57[a]	12.33 ± 0.33[b]	11.33 ± 0.33[b]	*
28	9.00 ± 0.57[c]	15.00 ± 0.57[a]	11.33 ± 0.33[b]	10.33 ± 0.33[cb]	*

*: P<0.05; Means followed by same letter in rows do not differ statistically from one another by the Tukey test at 5% probability; MOLM: *Moringa oleifera* Leaf Meal; SBM: Soybean meal; T_1: Ration containing 0% MOLM; T_2: Ration containing 5% MOLM; T_3: Ration containing 10% MOLM; T_4: Ration containing 15% MOLM; EST: Egg Storage Time; d: days.

Discussion

Inclusion of MOLM in the diets of hens at different levels (5%, 10% and 15%) showed a significant effect on their feed intake, BW change and FCR in the current study. This was similar with the finding of Olugbemi et al. [22] who noted that addition of 10% and 20% MOLM to the laying hen diet increases these parameters. Similarly, Kakengi et al. [23] reported that substitution of MOLM for sunflower seed meal in ISA brown breed significantly increased feed intake and FCR. The result of the current study was also consistent with those reported for broilers, were supplementation with 5% MOLM showed significantly better FCR as compared to the 0%, 3% and 7% MOLM containing experimental diets [24]. But the present study did not agree with the finding of Etalem et al. [25] who noted that addition of MOLM on Dominant CZ layers at 5% had no effect on average feed intake, final BW and FCR. Olugbemi et al. [21] also found that addition of 5% MOLM to broilers' diet had no significant effect on FCR and final BW when compared to a diet free of MOLM. The improvement in BW and FCR in the present study might be attributed to the rich content of nutrients in MOLM and antimicrobial properties of moringa.

Both internal and external egg quality in the present study were affected positively by the dietary substitution of SBM by MOLM at different levels in dual purpose Koekeok hens. Weight of sampled eggs and albumen weight, egg length, albumen height, yolk index, and yolk color, shell weight and yolk height, yolk weight were all improved especially at 5% MOLM inclusion. This was consistent with the finding of Etalem et al. [24] who reported a better egg quality obtained from hens fed 5% MOLM in the total ration. Improvement of albumen height in the present study was also agreed with the findings observed by Price, et al. [26] and Kaijage *et al.* [27] but inconsistent for improvement of yolk index. The higher the yolk index and Haugh unit, the more desirable is the egg quality [28] which resulted from the present study. This was also in agreement with the reports of Bhatnagar et al. [29] who conducted feeding MOLM to ISA brown breed at the levels of 5,10 and 20%, at lower levels improved egg quality and higher levels resulted in lower productivity and poorer egg quality indices. Improvement of egg weight in the current study was similar with Kakengi et al. [22] where substitution of sunflower with MOLM at 5% levels in the diet showed a positive effect on egg weight. The decrease in weight at higher levels of MOLM inclusion in the present study and others were also not clear but probably was due lower energy and CP availability and also associated with lower digestibility of CF component reported in various other leaf meals. Increasing of egg weight due to increase in weight of albumen and yolk especially for T_2 might be the main cause of improvement in Haugh Unit in the present study. This was also in agreement with Nobakht and Moghaddam, et al. [30] who noted a positive correlation between Haugh Unit and quality of egg components (yolk and albumen).

In the present study, the yolk color showed an increasing trend as the amount of MOLM increased in the ration. This was in line with the findings of Olugbemi et al. [21]; Etalem et al. [24] who observed that MOLM as a good pigmenting agent of poultry products due to its rich xanthophylls content. Egg yolk color is a very important factor in consumer satisfaction and influences human appetite [31], with a preference for golden yellow to orange yolk color [32]. Similarly, Jacob et al. [33] noted that yolk color is a key factor in any consumer survey relating to egg quality. The intense yellowish yolk color recorded in our study for eggs produced from birds on diets containing MOLM confirms its viability as a yolk-coloring agent, which can enhance the marketability of the eggs. Good shell thickness is an also important bio-economic trait in commercial egg production as it may help to reduce the percentage of cracked eggs and decrease the rate of loose for producers which supported by the present study.

The significant effect in shelf life of eggs in terms of pH of yolk and albumen at different storage time was in line with the findings of different researchers [34-37]. The decline in albumen and yolk pH deterioration rate was also characterized by Pappas et al. [38] as a function of the antioxidant status of egg contents. They proposed that organic selenium enhances the egg's antioxidant status by upgrading the glutathione peroxidase activity in yolk and albumen. This in turns slows the process of lipid and protein oxidation during storage period; hence more valuable egg quality by extended storage time which is consistent with the antioxidant properties of *M. oleifera* [39,40] that observed in the present study. *M. oleifera* is among the most promising species based on their high antioxidant activity, high contents of micro-nutrients and phytochemicals that could help in stability and shelf life of poultry product [41]. The flavonoids such as quercetin and kaempferol were identified as the most potent antioxidants in moringa leaves [42]. Similarly, Siddhuraju and Becker, et al. [43] noted their antioxidant activity was higher than the conventional antioxidants such as ascorbic acid, which is also present in large amounts in moringa leaves and used to prolong shelf life of poultry products. The improvement in shelf life of eggs in the present study as a result of MOLM inclusion could be related to the presence of the antioxidants mentioned [44-46] that phenolic compounds have a high antioxidant activity through three mechanisms: free-radical scavenging activity, transition-metal-chelating activity, and/or singlet-oxygen quenching capacity. Feeding of MOLM for dual purpose Koekoek hens in the present study improves the shelf life of an egg probably by minimizing the rapid increasing of the yolk pH. Similar probable reason also made [47] as some synergistic effects among ascorbic acid, α-tocopherol, and ß-carotene have been against oxidation. During storage of eggs, the pH of the albumen increases from oviposition 7.6 to 8.5 [48] and this is thought to be related to the deterioration of albumen quality. Li-Chan et al. [49] also noted during storage, the albumen pH increases at a temperature dependent rate to a maximum value of about 9.7. Different researchers [34-37] also noted a shift in albumen pH from 8.35 at day 7 to 9.08 and 9.29 after 14 and 21days of storage, respectively. This indicated that the result found in the present study was valuable regarding with improving shelf life of an egg in terms of pH of albumen. Yolk pH in the current study also lower than the value obtained by Li-Chan et al. [49] that reported in newly laid eggs, the yolk pH is in general close to 6.0; however, during storage it gradually increases to reach 6.4 to 6.9. This implies that, feeding of MOLM for dual purpose Koekoek hens in the present study improves the shelf life of an egg in terms of minimizing the rapid increasing of the yolk pH.

The decrease in albumen height, albumen weight and Haugh unit with storage time was consistent with the reports of Keener et al. [50] and Silversides and Budgell, et al. [38]. Storage time has inverse relationship with height of albumen. During egg storage, the quality of the vitelline membrane declines, making the yolk more susceptible to breaking and decreases its weight [51]. In the current study, there was a decrease in yolk weight but there was no breakage except eggs from the control group. This implies that moringa leaf may have a promising potential in extending the shelf life of poultry products. Niekerk, et al. [52] reported that storage for one week at 25°C will reduce the Haugh unit up to the limit of acceptable freshness (70 HU), whereas storage for one week at 8°C will result in eggs that are still very fresh (85 to 90 HU). This indicated that eggs from hens fed MOLM in the present study were still under the grade of AA according to USDA [53] up to four week storage at room temperature.

The significant decrease of yolk and albumen measurements relating with storage time was in line with the finding of Jin et al. [54]; Gavril and Usturoi, et al. [55] and Tebesi et al. [56]. The range of values observed in the current study differed from values reported by Tayeb, et al. [57] on effects of storage length on egg quality parameters of laying hens. Wojdylo et al. [58] noted that many herbs, spices, and their extracts have high antioxidant capacity, such as, moringa (*M. oleifera*), Oregano (*O. vulgare*), Rosemary (*R. officinalis*), and Sage (*S. officinalis*) to improve quality of poultry products in terms of prolonging their shelf life and this was in line with the current study.

Conclusion and Recommendations

- Inclusion of MOLM at 5% (T_2) dietary level improved BW change, feed conversion ratio, egg quality parameters (egg length, egg width, egg shape index, albumen weight and height, yolk weight and height, Haugh unit, yolk color, yolk length and yolk index) and the egg shelf life.
- The study showed that obtained responses due to inclusion of MOLM at 5% suggest the shrub to have a potential as alternative protein feed ingredient and as well as it may serve as a feed additive to keep the product quality in the poultry sector.

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