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Moringa and Sesbania Leaves in Layer Chicken Pens as an Edible Environmental Enrichment: Effects on Performance and, Physical and Organoleptic Properties of Eggs

Research Article

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ABSTRACT

Enrichment of layer chicken environment with physical, sensory, or stimulatory additions reported to have numerous beneficial effects. Hanging readily available tropical leguminous leafy materials such as Moringa and Sesbania in layer chicken pens can provide an additional amount of nutrients while serving as an environmental enrichment means. This study investigated the effects of hanging Moringa and Sesbania leaves as edible cage enrichments on performance, physical and organoleptic properties of egg and litter characteristics. Giving a completely randomized design experiment, 75 weeks old RIR layers (n=80) were allocated into 16 pens. Treatments were hanging two bundles of *Moringa oleifera* (MOL) leaves (T1), one bundle of MOL and one bundle of *Sesbania grandiflora* (SGL) leaves (T2), two bundles of SGL (T3) and no leaves hanging (T4). Egg production, and feed and leafy material intake were recorded for 42 days. Eggs were analyzed for physical properties. A semi-trained panel (n=25) conducted a sensory evaluation for eggs. The frequency of visiting feeders, drinkers, and leaves bundles was recorded using scan sampling techniques. Results showed that birds more preferred to eat SGL than MOL. Hanging of MOL or SGL alone or as two separate bundles increased body weight, egg weight, percentage of egg albumen, egg length, and eggshell thickness significantly. Colour, flavor, and overall acceptability of yolk color and flavor and aroma of egg white were positively influenced (P<0.05) by the hanging of leafy materials. Birds in pens with MOL and SGL exhibited more exploratory behaviors toward leaf bundles. Hanging of leafy materials increased the litter nitrogen content (P<0.05) as well. The study concludes that hanging MOL or MOL MOL leaves in layer chicken pens has positive impacts on physical and organoleptic properties and welfare while increasing litter nitrogen content.

KEY WORDS cage, egg physical, enrichment, hanging, *Moringa oleifera*, organoleptic, *Sesbania grandiflora*.

INTRODUCTION

Both conventional and non-cage alternative systems such as aviaries, barns, free-range facilities, and furnished cages are reported to have numerous negative impacts on the welfare of layer chickens (Campbell *et al.* 2019). Numerous studies (McAdie *et al.* 2005; Campbell *et al.* 2018; Liebers *et al.* 2019; van Staaveren *et al.* 2021; Xu *et al.* 2022) have shown that environmental enrichment of layer houses induces welfare-friendly behaviors while lowering the physiological stress responses. Structural adjustments in the houses (perches) and the introduction of peckable but not edible environmental enrichments (balls, brooms, buckets, ropes, dog toys, etc.) are among the most widely used cage enrichment strategies (Bari *et al.* 2020). Some of the non or less-edible peckables such as straw (Cronin *et al.* 2018) and silage (Steenfeldt *et al.* 2007) have produced negative impacts on production performance and gut morphology. Meanwhile, some studies (Schreiter *et al.* 2020a, Schreiter *et al.* 2020b) have suggested the introduction of edible enrichments as a practicable approach to reduce feather pecking with no adverse effects on the laying rate. However, care should be given when selecting edible cage enrichment materials since some of them such as carrots have been reported to reduce the feed intake (Steenfeldt *et al.* 2007).

Various leaf meals including cassava (Bakare *et al.* 2021), neem (Gobezie, 2022), sweet potato (Okereke *et al.* 2022), moringa (Abbas, 2013; Gobezie, 2021), and Sesbania (Khan *et al.* 2009; Ung *et al.* 2012) have been reported varying level of effectiveness in poultry. Moringa (*Moringa oleifera*) is an underutilized leguminous tropical tree. Being leguminous plants leaves of both Moringa and Sesbania are high in protein with a well-balanced amino acid profile, fat, vitamins A, and C, calcium, iron, potassium, magnesium, selenium, and zinc (Abbas, 2013; Liyanage *et al.* 2014). Recently, Mahfuz and Piao (2019) reviewed the use of Moringa leaf meal as a feed ingredient in poultry diets. Bhokre *et al.* (2022) reported that dietary inclusions of moringa leaf meal up to a maximum of 10% enhance the layer performance and the relative weight of albumin in eggs. Both Moringa and Sesbania are widely available in tropical regions and farmers widely use these plants in animal feeds, particularly for ruminants. However, we were unable to find any study where the leaves of these plants have been used separately from diets. Provision of these materials can be considered as cage enrichment as well since the practice may alter the behavior of the birds. Due to their excellent nutritive value, Moringa and Sesbania leaves may supply an additional level of nutrients, if birds consume them. Since hanging leafy materials without being incorporated into the diets mimics a choice-feeding situation (Henuk and Dingle, 2002), it is suggested that this strategy may offer the advantages of choice-feeding as well. In these circumstances, the present study investigated the effect of hanging Moringa and Sesbania leaf meal as an edible environmental enrichment on the production performance and physical and organoleptic properties of layer chicken.

MATERIALS AND METHODS

Ethical clearance

The experimental protocol was approved by the Ethical Review Committee of the Faculty of Agriculture, University of Ruhuna, Sri Lanka (RU/AT/013/2021).

Experimental birds and design and treatment allocation

A total of eighty Rode Island Red hens (75 weeks of age) were subjected to 6 weeks of trial. The study followed a Complete Randomized Design (CRD) with four treatments and four replicate pens of five birds. Each pen was provided with a feeder and a bell-shaped drinker. The layer birds were distributed into 16-floor pens (size 1.5 m × 1 m) by balancing the weight. Birds were acclimatized to pens for 6 weeks before commencing the study. Pens were randomly allocated into four treatments. Except in control groups, two leaf bundles were hung in each pen as follows; Moringa + Moringa (T1), Moringa + Sesbania (T2), Sesbania + Sesbania (T3). Four pens that were not provided with any leafy material were considered as the control (T4). Weighed-fresh leaf bundles were hung every other day. The difference between the leaf bundles offered and the leftover leaf bundles + and leaves on the litter was considered the leafy material intake. The body weights were recorded on the first day and, 3 and 6 weeks after the hanging of leafy materials (at the end of the experiment). Egg production, and the intakes of feed, water, and leafy materials were recorded for five weeks. Three eggs were collected randomly from each pen (a total of 48 eggs) before and after the experiment to determine the egg's physical traits in terms of egg weight, yolk percentage, albumen percentage, shell percentage, shell thickness, length, and width. The yolk color was determined using the Rotche yolk fan.

Behavior study

The behavioral study was conducted one week after the introduction of leafy materials. The behavior of the birds in one pen was observed for ten minutes per day for thirteen days consecutively. The number of times all five birds engaged in feeding, drinking, eating leafy materials, and eating litter (interaction with litter) was recorded in each ten minute session. Starting from one pen, all 16 pens were observed on a given day. The first pen of observation was systematically changed daily. To habituate the observer to the birds and to ensure the consideration of undisturbed behavior, the first and last 2.5 minutes of each observation event of a pen was removed from the analysis.

Litter quality

Four litter samples were collected from each pen at the end of the experiment and pooled. Pooled litter samples were analyzed for dry matter, nitrogen, pH, and electrical conductivity (EC).

Sensory evaluation

Sensory sample preparation and evaluation were conducted according to Hayat *et al.* (2010). Randomly selected eggs from each treatment (3 eggs from each pen) were boiled in a container with a lid by adding 900 mL of tap water. The gas range was kept at a maximum level and allowed 8.5

min for the boiling process. Subsequently, the eggs were kept in the same container for 20 min after opening the lid. The eggs were allowed to cool up to the ambient temperature under tap water after draining the hot water. Peeled eggs were cut into quarters and delivered to sample plates. Semi-trained panelists (n=25) were selected from students and the staff of the Faculty of Agriculture, Eastern University, Sri Lanka. The panelists had earlier served in sensory evaluation panels. Before the sensory evaluation, panelists were briefed about the research objectives and what each sensory quality means. One quarter from each treatment was kept on separate plates with one control sample and four other blind-coded test samples (one control and four samples from each treatment including the control treatment) and presented to the panelists. Those blind-coded samples were estimated how those were different from the control sample concerning) Color: the color of the egg yolk and egg white; b) aroma: the odor of the whole egg; c) flavor: the distinctive aroma and taste of the yolk and egg white; and d) overall difference: an integrated sensation based on aroma, flavor, aftertaste, and presence of off-flavor (if any) were tested as the sensory attributes. Panelists were asked to rate the difference of each attribute between each sample and the control using a 5-point Likert scale where 5- much better and, 1- very bad. Additionally, a comment opportunity was added for each attribute and requested to comment on what they thought about the difference of particular attributes between the control and the treatments. Before commencement, the panelists were informed that one of the test samples might be the same as the control.

Data analysis

Body weight, egg production, leafy material intake, water: feed ratio (W:F ratio) and litter quality parameters, and behavioral data were statistically analyzed using the General Linear Model procedure of the SPSS version 20.0, IBM Corporation, Somers, NY, USA (SPSS, 2011). Treatment means were compared by the Duncan multiple range test. Kruskal-Walli's test was used to analyze the egg organoleptic traits. The level of significance was fixed at $P < 0.05$.

RESULTS AND DISCUSSION

Carrot, silage, (Steenfeldt *et al.* 2007), straw (Cronin and Glatz, 2020) and alfalfa (Schreiter *et al.* 2020a) have been used as edible cage enrichments for laying hens. Though numerous studies have reported the effects of dietary inclusion of Moringa (Bidura *et al.* 2020; Tamiru *et al.* 2020; Abdel-Wareth and Lohakare, 2021) and Sesbania (Kejela *et al.* 2020) on layer chicken, no attempts have been done to use those materials as edible cage enrichments. Consequently, where appropriate, the results of this study were compared with the studies where Moringa leaves have been used as dietary ingredients.

Importantly, hanging MOL and SGL had no significant effect on feed intake as Steenfeldt *et al.* (2007) reported for carrots. Hanging of MOL or SGL bundles, alone or as two separate bundles, for six weeks increased the live weight of the chicken ($P<0.05$) (Table 1).

In line with our study, Schreiter *et al.* (2020a), have also reported an increase in body weight when hard-pressed alfalfa bails were provided as edible cage enrichments in layer hen pens. Dietary inclusion of Moringa leaves has also been reported to increase body weight (Melesse *et al.* 2011; Voemesse *et al.* 2019). However, Mabusela *et al.* (2018) reported that the dietary inclusion of moringa leaves reduced body weight.

When Moringa was the only one leafy material provided (T1), the consumption of it was significantly higher than the intake of Moringa leafy material bundle of the T2 birds who received two types of leafy material bundles (Table 2). Similarly, Sesbania intake was also significantly higher when it was the only leafy material offered, compared to the situation in which bundles of two types of leafy materials were available. Meanwhile, Sesbania intake in the T3 (two bundles of Sesbania) was substantially higher than the Moring intake in T1 (Moringa only). These observations suggest a clear preference towards Sesbania over Moringa. Interestingly, the total leafy material intake was significantly higher when two types of leafy materials were provided than when either Sesbania or Morinaga was provided alone. In contrast, Voemesse *et al.* (2019) reported a lower feed intake of Moringa leaf during the laying period of hens.

Egg production wasn't significantly affected by the treatments ($P>0.05$). However, the highest egg production was recorded by the layers assigned under T3 whereas the lowest was recorded from the control group of layers. The equal egg production was recorded in T1 and T2 (Table 3).

Abou-Elezz *et al.* (2011) found that the inclusion of Moringa at lower rates had a greater beneficial nutritional impact on egg production whereas the higher inclusion rates resulted in a significant reduction of laying rate and egg mass. In general, the chicken digestive tract has a limited capacity to efficiently digest foods high in fiber. Hence, the higher bulkiness associated with higher levels of leaf meals might be a reason for reducing feed intake which led to a deficiency in required nutrients for optimum production (Son *et al.* 2002; Esonu *et al.* 2006; Ige *et al.* 2006). Feed conversion ratio (FCR) was affected due to the hanging of different leafy materials (Table 3).

Table 1 Effect of hanging Moringa, and Sesbania leaves bundles in pens of layer chicken on body weight (g) (Mean±SEM)

Weeks after leafy material provision	Moringa + Moringa	Moringa + Sesbania	Sesbania + Sesbania	No leafy material hanging	P- value
0	1820±25.75	1822.5±32.13	1820±28.35	1800±34.02	0.198
3 weeks	1880±18.98	1862.5±21.72	1885±30.80	1852.5±30.23	0.796
6 weeks	1880±28.65^{b}	1910±34.14^{b}	1932.5±23.02^{b}	1820±15.56^{a}	0.021

The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 2 Leafy material intake under different treatments (g/bird/day) (Mean±SEM)

Trait	Moringa + Moringa	Moringa + Sesbania	Sesbania + Sesbania	P-value
MOL intake	6.70±0.19^{a}	5.32±0.08^{b}		0.000
SGL intake		5.94±0.11^{a}	8.65±0.30^{c}	0.003
Total intake	6.70±0.19^{a}	11.26±0.31^{b}	8.65±0.30^{c}	0.000

MOL: *Moringa oleifera* and SGL: *Sesbania grandiflora*.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 3 Layer hen performances and W:F ratio under different types of leafy material hanging

Parameter	Moringa + Moringa	Moringa + Sesbania	Sesbania + Sesbania	No leafy material hanging	P-value
Egg production (%)	50.39±3.10	49.61±2.97	53.85±2.95	43.08±2.60	0.12
FCR	1.8±0.1^{ab}	1.7±0.1^{a}	1.8±0.03^{ab}	1.9±0.02^{b}	0.028
Water:Feed ratio	2.25±0.30	2.03±0.12	1.80±0.18	2.46±0.62	0.602

FCR: feed conversion ratio.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 4 Egg quality parameters before and after inclusion of different leafy material (Mean±SEM)

Egg quality parameters		Moringa + Moringa	Moringa +Sesbania	Sesbania + Sesbania	No leafy material hanging	P-value
Egg weight(g)	B.E.	61.9±1.5	60.0±1.3	62.4±1.7	57.7±2.1	0.211
	A.E.	60.8±0.9^{a}	66.5±1.3^{b}	67.1±1.2^{c}	57.6±1.2^{d}	0.000
Egg yolk (%)	B.E.	25.4±1.9	25.4±1.0	27.6±1.2	27.3±1.9	0.630
	A.E.	26.1±1.1	25.7±0.9	26.1±0.7	27.4±1.1	0.647
Egg Albumen (%)	B.E.	59.9±1.2	60.4±1.6	57.8±1.6	58.4±2.1	0.664
	A.E.	56.8±1.5^{a}	57.4±0.8^{a}	56.9±0.8^{a}	53.6±0.8^{b}	0.045
Egg shell (%)	B.E.	20.0±0.4^{a}	20.0±0.6^{a}	20.2±0.7^{a}	22.3±0.6^{b}	0.016
	A.E.	16.8±1.1	16.8±0.5	17.0±0.6	17.4±0.4	0.204
Egg length (mm)	B.E.	57.1±0.8	57.2±0.7	55.9±0.8	56.1±0.9	0.587
	A.E.	59.7±0.6^{b}	59.8±0.6^{c}	60.1±0.6^{d}	55.7±0.6^{e}	0.000
Egg width (mm)	B.E.	42.3±0.5	41.4±0.4	41.5±0.4	41.1±0.6	0.351
	A.E.	43.7±0.4	43.7±0.5	43.8±0.6	42.8±0.3	0.486
Egg shell thickness (mm)	B.E.	0.2±0.03	0.2±0.05	0.2±0.01	0.2±0.08	0.629
	A.E.	0.3±0.05^{b}	0.3±0.08^{c}	0.3±0.02^{d}	0.2±0.02^{e}	0.010
Yolk color	B.E.	2±0.2^{a}	2±0.1^{a}	1±0.1^{b}	2±0.2^{a}	0.018
	A.E.	4±0.2^{c}	5±0.3^{d}	5±0.3^{e}	2±0.4^{a}	0.000

B.E: before experiment and A.E: after experiment.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Compared to the situation where there was no leafy material provision, birds reported significantly better FCR when pens were provided with both MOL and SGL (T2). Effects of hanging leafy materials on FCR have not been reported. Reports on the effects of dietary Moringa leaf inclusion on FCR are not conclusive. For example, Abdel-Wareth and Lohakare (2021) and Paguia *et al.* (2014) have reported no effects of Moringa leaf meal inclusion on the FCR of layer chicken. Meanwhile, Abou-Elezz *et al.* (2011) reported inferior FCR values, particularly at higher inclusion levels.

Leafy material hanging did not alter the W:F ratio (P>0.05) (Table 3). The total intake of leafy materials was significantly high when two leafy materials of MOL and SGL were hung. Both of those materials are high in some nutrients such as protein and fat (Kumar *et al.* 2017; Bhosale *et al.* 2021).

Table 5 Mean ranks of sensory quality parameters of eggs of layer chicken provided with leafy materials

Parameter	Moringa + Moringa	Moringa + Sesbania	Sesbania + Sesbania	No leafy material hanging	P-value
Egg white colour	55.0	45.0	56.0	47.0	0.35
Egg yolk colour	55.0[a]	56.0[a]	71.0[a]	20.0[b]	0.00
Egg white flavor	57.0[a]	46.0[a]	61.0[b]	39.0[c]	0.01
Egg yolk flavor	54.0[a]	62.0[a]	60.0[a]	27.0[b]	0.00
Egg white aroma	58.0[a]	57.0[a]	51.0[a]	36.0[b]	0.01
Egg yolk aroma	50.0[a]	55.0[a]	69.0[a]	29.0[b]	0.00
Overall acceptability (egg white)	58.0	48.0	55.0	41.0	0.06
Overall acceptability (egg yolk)	53.0[a]	59.0[a]	63.0[a]	28.0[b]	0.00

The means within the same row with at least one common letter, do not have significant difference (P>0.05).

Table 6 Engagement in selected behaviours by layers chicken (frequency/five minutes per five bird) in pens provided with Moringa or Sesbania leaves as edible cage enrichments (Mean±SEM)

Parameter	Moringa + Moringa	Moringa + Sesbania	Sesbania + Sesbania	No leafy material hanging	P-value
Frequency of drinking	3.5±0.1	3.3±0.1	3.4±0.2	3.4±0.1	0.882
Frequency of eating Moringa leaf	3.4±0.1[a]	3.1±0.1[b]			0.000
Frequency of eating Sesbania leaf		3.5±0.1[a]	4.5±0.2[b]		0.000
Frequency of eating commercial feed	3.7±0.1	3.5±0.1	3.4±0.3	3.7±0.3	0.517
Frequency of eating litter	3.3±0.1	3.6±0.3	3.1±0.1	3.3±0.4	0.355

The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 7 Litter quality parameters after the experiment (Mean±SEM)

Litter quality parameters	Moringa + Moringa	Moringa + Sesbania	Sesbania + Sesbania	No leafy material hanging	P-value
DM%	40.8±2.5	40.4±0.2	46.2±3.1	46.5±1.7	0.128
pH	8.2±0.09[a]	8.7±0.1[b]	7.9±0.02[a]	8.5±0.08[b]	0.000
N%	1.84±0.04[a]	1.90±0.04[a]	1.85±0.04[a]	1.59±0.02[b]	0.000
EC (dS/m)	4.27±0.10[a]	3.31±0.10[b]	4.25±0.08[a]	3.41±0.12[b]	0.001

The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Therefore, the positive effects due to the provision of additional nutrients from those leafy materials on live weight and egg weight cannot be excluded.

Egg width, eggshell %, and egg yolk % were not affected by the hanging of leafy materials in pens (P>0.05) (Tale 4). Interestingly, hanging MOL and SGL in pens increased the egg weight, egg length, eggshell thickness, and yolk colour whereas the albumen % decreased significantly (P<0.05). Schreiter *et al.* (2020a) have also reported that the provision of hard-pressed alfalfa bail as edible cage enrichments in layer chicken pens resulted in creased egg weight. Several studies (Abou-Elkhair *et al.* 2020; Bidura *et al.* 2020) have also reported that moringa leaf meal increased the yolk colour index. Bidura *et al.* (2020) also reported higher shell thickness due to the dietary inclusion of moringa leaf meal. Positive effects reported by the birds provided with leafy materials could be due to the additional nutrients that resulted from the ingestion of leafy materials. Sesbania and Moringa leaves are reported to contain a range of nutrients (Kumar *et al.* 2017; Bhosale *et al.* 2021) including beta carotene (Glover-Amengor *et al.* 2017) that is required for higher yolk colour. Since consumers prefer eggs with higher yolk colour (Putri *et al.* 2021), Meanwhile, egg consumption has been negatively affected due to the claim that there is a positive association between egg consumption and cardiovascular diseases related mortalities (Abou-Elezz *et al.* 2011; Sugano and Matsuoka, 2021). In this context, a relative increase of albumin and higher yolk colour reported by the birds provided with leafy materials are of particular importance.

Interestingly, except egg white colour and overall acceptability, all other organoleptic properties such as color, flavor, aroma, and the overall acceptability of the yolk and, the white aroma and the flavor of egg white were also significantly improved due to the provision of MOL and SGL, each alone or as separate bundles (Table 5). The higher egg yolk colour reported by the birds provided with leafy materials can be attributed to the additional supply of carotene as reported by many authors (Lu *et al.* 2016; Garcia *et al.* 2021; Sharmin *et al.* 2021). However, it is not clear as to why the sensory properties of the egg white were improved due to the provision of MOL and SGL.

The effects of hanging MOL and SGL on some selected behaviors are represented in Table 6. It revealed that there wasn't a marked effect on drinking, eating litter, and eating commercial feed crumbles due to the provision of leafy materials (P>0.05). However, there an increased frequency of eating Sesbania (either under T2 or T3) was observed, which goes in line with the observed highest intake of Sesbania (P<0.05). Interestingly, when two types of leafy materials (MOL and SGL) were hung in the same pan, birds frequented both materials at a more or less similar rate. In all three treatments, the frequency of vising feeder was more or less similar. These observations suggest that the provision of leafy materials has increased the exploratory behavior of the birds. Furthermore, birds might have pecked the fallen leaves thereby stimulating foraging behavior as well. Da Silva (2021) showed that the provision of straw bales in broiler pens as environmental enrichment improved the welfare by increasing birds' active exploratory behaviors. In this context, hanging leafy materials in layer hen pens is suggested to be welfare welfare-friendly practice.

Dry matter (DM %), pH, N %, and EC of the litters are presented in Table 7. The inclusion of leafy materials had no significant effect on the DM % of the litter (P>0.05). pH of the T1 and T3 litters were significantly lower than that of control (P<0.05). Compared to control, hanging of leafy materials significantly increased the litter N % (P<0.05). This could be due to ingestion of leafy materials of high N contents and or the mixing of those leaves with litter. Since poultry litter is widely used as an organic fertilizer, higher N contents in the litters of the layers that are provided with MOL and SGL can increase the organic fertilizer value of those litter.

CONCLUSION

When presented separately without incorporating into feeds, layer chicken preferred Sesbania leaves to Moringa. Hanging of Moringa and Sesbania leaves each alone or as two separate bundles, though had no effects on the egg production rate, increased the egg weight, shell thickness, and the relative weight of the albumin. The provision of that leafy material also improved the organoleptic properties of the eggs, particularly that of yolk. Increased exploratory and, litter nitrogen contents were also identified as added advantages of hanging Moringa and or Sesbania leaves as a cage enrichment means in layer chicken pens.

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REFERENCES

Abbas T.E. (2013). The use of *Moringa oleifera* in poultry diets. *Turkish J. Vet. Anim. Sci.* **37(5),** 492-496.

Abdel-Wareth A.A.A. and Lohakare J. (2021). *Moringa oleifera* leaves as eco-friendly feed additive in diets of hy-line brown hens during the late laying period. *Animals.* **11(4),** 1-10.

Abou-Elezz F.M.K., Sarmiento-Franco L., Santos-Ricalde R. and Solorio-Sanchez F. (2011). Nutritional effects of dietary inclusion of *Leucaena leucocephala* and Moringa oleifera leaf meal on Rhode Island Red hens' performance. *Cuban J. Agric. Sci.* **45(2),** 163-170.

Abou-Elkhair R., Abdo Basha H., Slouma Hamouda Abd El Naby W., Ajarem J.S., Maodaa S.N., Allam A.A. and Naiel M.A. (2020). Effect of a diet supplemented with the *Moringa oleifera* seed powder on the performance, egg quality, and gene expression in Japanese laying quail under heat-stress. *Animals.* **10(5),** 809-817.

Bakare A.G., Zindove T.J. Iji P.A., Stamatopoulos K. and Cowieson A.J. (2021). A review of limitations to using cassava meal in poultry diets and the potential role of exogenous microbial enzymes. *Trop. Anim. Health Prod.* **53(4),** 426-435.

Bari M.S., Cohen-Barnhouse A.M. and Campbell D.L.M. (2020). Early rearing enrichments influenced nest use and egg quality in free-range laying hens. *Animals.* **14(6),** 1249-1257.

Bhokre C., Gadhe K. and Joshi A. (2022). Assessment of nutritional and phytochemical properties of Sesbania grandiflora flower and leaves. *J. Pharm. Innov.* **11(6),** 90-94.

Bhosale T.R., Chavan M.K. and Dnyandeo T. (2021). Proximate analysis of *Azadirachta indica* and *Moringa oleifera L.* leaves as feed additives for ruminants. *J. Pharm. Innov.* **10(12),** 1884-1886.

Bidura I.G.N.G., Partama I.B.G., Utami I.A.P., Candrawati D.P.M.A., Puspani E., Suasta I.M. and Warmadewi D.A. (2020). Effect of *Moringa oleifera* leaf powder in diets on laying hens performance, β-carotene, cholesterol, and minerals contents in egg yolk. *IOP Conf. Ser. Mater. Sci. Eng.* **823(1),** 1-9.

Campbell D.L.M., Hinch G.N., Downing J.A. and Lee C. (2018). Early enrichment in free-range laying hens: Effects on ranging behaviour, welfare and response to stressors. *Animals.* **12(3),** 575-584.

Campbell D.L.M., De Haas E.N. and Lee C. (2019). A review of environmental enrichment for laying hens during rearing in relation to their behavioral and physiological development. *Poult. Sci.* **98(1),** 9-28.

Cronin G.M. and Glatz P.C. (2020). Causes of feather pecking and subsequent welfare issues for the laying hen: a review. *Anim. Prod. Sci.* **61(10),** 990-1005.

Cronin G.M., Hopcroft R.L., Groves P.J., Hall E.J.S., Phalen D.N. and Hemsworth P.H. (2018). Why did severe feather pecking and cannibalism outbreaks occur? An unintended case study while investigating the effects of forage and stress on pullets during rearing. *Poult. Sci.* **97(5),** 1484-1502.

Da Silva L.M.I., Almeida Paz I.C.D.L., Chaves G.H.C., Almeida I.C.D.L., Ouros C.C.D., Souza S.R.L.D., Milbradt E.L., Caldara F.R., Satin A.J.G., Costa G.A.D. and Glavina A.S.G. (2021). Behaviour and animal welfare indicators of broiler chickens housed in an enriched environment. *PLoS One.* **16(9),** e0256963.

Esonu B.O., Opara M.N., Okoli I.C., Obikaonu H.O., Udedibie C. and Iheshiulor O.O.M. (2006). Physiological response of laying birds to neem (*Azadirachta indica*) leaf meal-based diets: Body weight organ characteristics and hematology. *Online J. Health Allied Sci.* **5(2),** 1-7.

Garcia R.G., Gandra E.R.S., Burbarelli M.F.C., Valentim J.K., Felix G.A., Lopes B.A., Bacha F.B., Melo C.M.F., Silva J.P., Komiyama C.M. and Caldara F.R. (2021). *Moringa oleifera*: An alternative ingredient to improve the egg quality of Japanese quail. *Arq. Bras. Med. Vet. Zootec.* **73,** 721-732.

Glover-Amengor M., Aryeetey R., Afari E. and Nyarko A. (2017). Micronutrient composition and acceptability of Moringa oleifera leaf-fortified dishes by children in Ada-East district, Ghana. *Food Sci. Nutr.* **5(2),** 317-323.

Gobezie E. (2021). Supplementation of *Moringa oleifera* leaf meal in layer chickens' feed: A review. *World's Vet. J.* **11(2),** 202-207.

Gobezie E. (2022). Effect of Neem (*Azadirachta indica*) leaf powder on the growth performance and carcass quality of broiler chicken-A review. *J. Livest. Sci.* **21(13),** 152-158.

Hayat Z., Cherian G., Pasha T.N., Khattak F.M. and Jabbar M.A. (2010). Sensory evaluation and consumer acceptance of eggs from hens fed flax seed and 2 different antioxidants. *Poult. Sci.* **89(10),** 2293-2298.

Henuk Y.L. and Dingle J.G. (2002). Practical and economic advantages of choice feeding systems for laying poultry. *Worlds Poult. Sci.* **58(2),** 199-208.

Ige A.O., Odunsi A.A., Akinlade J.A. and Ojedapo L.O. (2006). Gliricidia leaf meal in layer's diet: Effect on performance, nutrient digestibility and economy of production. *J. Anim. Vet. Adv.* **5(6),** 483-486.

Kejela M., Diba D., Yusuf H., Ferede B. and Duguma G. (2020). Feed intake, weight gain and profitability of sasso chickens fed locally formulated rations at Wollega university, Nekemte, Ethiopia. *World Appl. Sci. J.* **38(5),** 404-415.

Khan M.K.A., Akbar M.A., Khaleduzzaman A.B.M. and Rahman M.E. (2009). Utilization of Leucaena and Sesbania leaf meals as protein. *Bangladesh J. Anim. Sci.* **38(1),** 123-131.

Kumar U., Murthy H.N.N., Singh K.C., Mahadevappa D., Rajeshwari Y.B., Siddeshwara N.C., Mateen A. and Guruprasad R. (2017). Biomass yield and chemical composition of sesbania. *Int. J. Sci. Environ.* **6(6),** 3264-3269.

Liebers C.J., Schwarzer A., Erhard M., Schmidt P. and Louton H. (2019). The influence of environmental enrichment and stocking density on the plumage and health conditions of laying hen pullets. *Poult. Sci.* **98(6),** 2474-2488.

Liyanage R., Jayathilaka C., Perera O.S., Kulasooriya S.A., Jayawardana B.C. and Wimalasiri S. (2014). Protein and micronutrient contents of *Moringa oleifera* (Murunga) leaves collected from different localities in Sri Lanka. *Asian J. Agric. Food Sci.* **2(4),** 264-269.

Lu W., Wang J., Zhang H.J., Wu S.G. and Qi G.H. (2016). Evaluation of *Moringa oleifera* leaf in laying hens: Effects on laying performance, egg quality, plasma biochemistry and organ histopathological indices. *Italian J. Anim. Sci.* **15(4),** 658-665.

Mabusela S.P., Nkukwana T.T., Mokoma M. and Muchenje V. (2018). Layer performance, fatty acid profile and the quality of eggs from hens supplemented with *Moringa oleifera* whole seed meal. *South African J. Anim. Sci.* **48(2),** 234-243.

Mahfuz S. and Piao X.S. (2019). Application of Moringa (*Moringa oleifera*) as natural feed supplement in poultry diets. *Animals.* **9(7),** 431-437.

McAdie T.M., Keeling L.J., Blokhuis H.J. and Jones R.B. (2005). Reduction in feather pecking and improvement of feather condition with the presentation of a string device to chickens. *Appl. Anim. Behav. Sci.* **93(1),** 67-80.

Melesse A., Tiruneh W. and Negesse T. (2011). Effects of feeding *Moringa stenopetala* leaf meal on nutrient intake and growth performance of Rhode Island Red chicks under tropical climate. *Trop. Subtrop. Agroecosyst.* **14(2),** 485-492.

Okereke C.O., Okereke I.H., Olaleru I.F. and Ukonu C.E. (2022). Potentials of sweet potato foliage as feed ingredient in Broiler diets. *Nigerian Agric. J.* **53(3),** 171-174.

Paguia H.M., Paguia R.Q., Balba C. and Flores R.C. (2014). Utilization and Evaluation of *Moringa oleifera L.* as Poultry Feeds. *APCBEE Proc.* **8(2013),** 343-347.

Putri F., Suryantini A. and Mulyo J.H. (2021). Consumer preference towards layer chicken eggs and native chicken eggs in Yogyakarta. *Adv. Econ. Bus. Manag.* **199,** 181-189.

Schreiter R., Damme K., Klunker M., Raoult C., von Borell E. and Freick M. (2020a). Effects of edible environmental enrichments during the rearing and laying periods in a littered aviary-Part 2: Physical development of pullets and performance, egg quality, and carcass composition in laying hens. *Poult. Sci.* **99(12),** 6685-6696.

Schreiter R., Damme K. and Freick M. (2020b). Edible environmental enrichments in littered housing systems: Do their effects on integument condition differ between commercial laying hen strains? *Animals.* **10(12),** 2434-2441.

Sharmin F., Sarker M.S.K., Sarker N.R. and Faruque S. (2021). Dietary effect of *Moringa oleifera* on native laying hens' egg quality, cholesterol and fatty-acid profile. *Italian J. Anim. Sci.* **20(1),** 1544-1553.

Son J.H., Ragland D. and Adeola O. (2002). Quantification of digesta flow into de caeca. *Br. Poult. Sci.* **43,** 322-324.

SPSS Inc. (2011). Statistical Package for Social Sciences Study. SPSS for Windows, Version 20. Chicago SPSS Inc., USA.

Steenfeldt S., Kjaer J.B. and Engberg R.M. (2007). Effect of feeding silages or carrots as supplements to laying hens on production performance, nutrient digestibility, gut structure, gut microflora and feather pecking behaviour. *Br. Poult. Sci.* **48(4),** 454-468.

Sugano M. and Matsuoka R. (2021). Nutritional viewpoints on eggs and cholesterol. *Foods*. **10(3),** 494-503.

Tamiru M., Ashagrie S., Alkhtib A., Getachew M., Demeke S., Hassen W., Worku Z. and Burton E. (2020). Performance of broilers and layers supplemented with *Moringa stenopetala* leaf meal under hot humid tropical conditions. *Anim. Prod. Sci.* **60(17),** 1987-1994.

Ung P., Kang K., Neang S., Cheat S. and Mob S. (2012). Effect of using Sun-Dried sesbania leaves in concentrate on growth rate of quail. *Int. J. Environ. Rural Dev.* **3(2),** 109-113.

van Staaveren N., Ellis J., Baes C.F. and Harlander-Matauschek A. (2021). A meta-analysis on the effect of environmental enrichment on feather pecking and feather damage in laying hens. *Poult. Sci.* **100(2),** 397-411.

Voemesse K., Teteh A., Nideou D., N'nanlé O., Tété-Benissan A., Oke O., Gbeassor M., Decuypere E. and Tona K. (2019). Chemical composition and some functional properties of Moringa, Leucaena and Gliricidia leaf meals. *European J. Poult. Sci.* **83,** 1-12.

Xu D., Shu G., Liu Y., Qin P., Zheng Y., Tian Y., Zhao X. and Du X. (2022). Farm environmental enrichments improve the welfare of layer chicks and pullets: A comprehensive review. *Animals.* **12(19),** 2610-2617.