# Egg Quality of Isa Brown Laying Hens Administered Varying Quantity of *Phyllanthus niruri* Leaf Meal

**Omobola Olufayo & Oluwabusayo Irivboje**
(Department of Agricultural Technology, Federal Polytechnic, Ilaro, Ogun State, Nigeria)
omobola.olufayo@federalpolyilaro.edu.ng; simbiat.kareem@federalpolyilaro.edu.ng

## Abstract

*The laying efficiency and egg quality of Isa brown chickens was examined in this research in relation to various doses of Phyllanthus niruri (stonebreaker) leaf meal. Six different feed regimens T1 (0% P. niruri), T2 (antibiotics), T3 (0.2% P. niruri), T4 (0.3% Phyllanthus niruri leaf meal), T5 (0.4% P. niruri) and T6 (0.5% P. niruri) were fed to an aggregate of 192 Isa brown pullets that were 24 weeks old, utilizing a completely randomized design, with 4 replicates of 8 birds each, and 32 birds per treatment. The 12-week experiment was conducted to measure egg production indices, data on external egg measures, egg production, and analysis were gathered. The feed interventions had a significant (P<0.05) impact on hen-day egg production. At the fourth (45.00%), eighth (76.50%), and twelfth (92.71%) weeks in lay, laying hens fed T6 0.5% PNLM showed improved performance. Egg width, shell thickness, and egg shape index did not change significantly (P>0.05) between treatments for any of the characteristics examined. The ranges for egg weight, egg length, and egg shape index were 58.75–61.50 g, 49.93–55.33 mm, and 77.51–78.16%, respectively. Comparing different treatment groups, the laying hens fed P. niruri leaf meal diets (T5) displayed the highest egg weight of 61.50 g and the highest egg length of 55.33 mm in T2. For enhanced egg quality and laying productivity, P. niruri leaf meal is advised as an additive.*

**ARTICLE HISTORY**

Received: July 6, 2023
Revised: July 19, 2023
Accepted: July 24, 2023

**Keywords**: Egg quality, Isa brown layers, laying performance, *Phyllanthus niruri*

**Citation**
Olufayo, O. & Irivboje, O. (2023). Egg Quality of Isa Brown Laying Hens Administered Varying Quantity of Phyllanthus niruri Leaf Mea. *International Journal of Women in Technical Education and Employment*, 4(1), 148 – 157.

## Introduction

Due to the unavailability and high cost of the traditional protein and energy sources used in animal production, feed availability continues to be the poultry industry's biggest concern. In underdeveloped nations where human protein Mean daily intake is 35 g much below recommended dose of 50 grams of protein daily by FDA, (2023), an important factor in bridging the protein shortfall is poultry production. In Nigeria, poultry goods (meat and eggs) are delectable and accepted, which transcends practically all cultural and religious borders (Onyimonyi, Olabode, & Okeke, 2009).

Intensification of meat and egg production will be necessary to meet the demand for daily animal protein consumption (meat and eggs), especially among the majority of urban population. In order to fulfill the demands of the burgeoning human population, chicken production has been intensified, which has led to overcrowding, the rapid spread of diseases, and the use of chemical growth stimulants in the production systems. Despite the challenges posed by the development of antibiotic resistance, which poses a present and future threat to both human and animal health, the necessity to maximize profit in an intensive system of production has encouraged the use of antibiotics and growth boosters (Wang, Liang, Li, Yang, Long & Yang, 2019).

Consumer pressure is mounting on feed producers to use fewer antibiotic growth promoters as feed additives and to discover substitutes for these substances in poultry diets. Modern scientific innovations are being used by feed makers in the form of novel natural feed additives (Attia, 2018). As a result, research is needed to determine the effects of *Phyllanthus niruri* leaf meal on the production indices and egg quality of Isa brown layer chickens.

## Materials and Methods

### Experimental site of the study

The investigation was done at The Federal Polytechnic Ilaro Research Farm Poultry Unit in Ogun State, which is in the South-Western Rainforest Belt of Nigeria, latitude 6.8940ºN of the equator, with a yearly rainfall of 1500 mm and a mean daily temperature of 28ºC.

### Management of the experimental hens and design

The experimental hens were bought as day olds and reared under strict supervision until they laid eggs. In a completely randomized design (CRD), birds were given a compounded layer diet twice daily, including varying amounts of *P. niruri* leaf meal, and water was available at all times.

### Measurement of internal and external egg qualities

Four eggs per replicate were sampled for egg quality evaluation at first lay, week 4, 8 and 12 of the laying period. Eggs for analysis were sampled, weighed and broken on a flat surface where the height of the albumen was measured with micrometer. Albumen weight which is the difference between the egg weight and the sum of weight of yolk and dry egg shell expressed as a percentage of the whole egg was determined. The yolk was separated from the albumen and weighed using Mettler top-loading weighing balance. Also, the diameter and height of yolk was measured. Yolk colour was determined with one of the 15 bands of the yolk colour fan of Roche Company. The yolk index was calculated as the percentage of yolk height to yolk diameter (Wu, Bryant, Gunawardana and Roland, 2007) stated as follows: Yolk index = (Yolk height, mm/yolk diameter mm) x 100

Egg weight, egg length and width, egg shape index, shell thickness and shell weight were measured. Using a vernier calliper, the length of the egg—which is defined as the distance along its longitudinal axis between its narrow and broad poles—was determined. The diameter of the largest part of the egg's circumference was measured to determine the egg's breadth with the same instrument. The egg's shape index was calculated using the width and length values. Egg shell was dried at room temperature and weighed. The relative shell weight was calculated by relating the shell weight to the weight of the egg. After removing the inner membrane, thickness was measured with micrometer screw gauge on broad, middle and narrow side. Haugh units were calculated from records of egg weight and albumen height as an indicator of interior egg quality (Wu et al. 2007).

Haugh unit = 100 x log10 (H - 1.7W0.37+ 7.56) where H = height of the albumen and W = egg weight.

Egg shape Index (ESI) was calculated as the percentage of the egg breadth (width) to the egg length (Panda, 1996) stated as follows:

Egg Shape Index = Width of egg (mm)/Length of egg (mm) x 100

### Statistical Analysis

The experiment was arranged in a completely randomized design (CRD). One way Analysis of Variance (ANOVA) was done using SAS (2010) package. Significant differences among treatments were determined using Duncan's Multiple Range Test (Duncan, 1955).

## Results

Table 1 displays the experimental birds that were supplemented with *P. niruri* leaf diet at the twelve-week period of lay as having mean quality of the egg's exterior and interior metrics. The following variables were taken into consideration: yolk weight, diameter, and height; albumen weight, diameter, and height; and weight of the egg, length, width, egg shape index, shell thickness, and weight. There is no significant differences between the treatments in any of the parameters that were looked at (P>0.05). The ranges for egg weight, egg length, and egg shape index were 58.75–61.50 g, 49.93–55.33 mm, and 77.51–78.16%, respectively. Comparing different treatment groups, the laying hens given *P. niruri* leaf meal diets (T5) displayed the highest egg weight of 61.50 g and the highest egg length of 55.33 mm in T2. The egg weights measured at the 12th week of lay were nearly within the range of the typical weight (62.8 g) noted by (ECD, 2006). The maximum albumen weight (37.50 g) and highest yolk colour (11.75) were both achieved by PNLM inclusion at 0.3% (T4) and 0.5% (T6), respectively.

*International Journal of Women in Technical Education and Employment*
*ISSN: 2811-1567. Volume 4 – Issue 1. July 2023*
*https://fpiwitedjournal.federalpolyilaro.edu.ng*

**Table 1: Effect of *P. niruri* leaf meal inclusion on egg quality (12th week in lay)**

| Parameters | T1 | T2 | T3 | T4 | T5 | T6 | SEM± |
|---|---|---|---|---|---|---|---|
| **External qualities** | | | | | | | |
| Egg wgt. (g) | 59.13 | 61.38 | 58.75 | 60.50 | 61.50 | 61.13 | 1.64 |
| Egg lgth (mm) | 54.13 | 55.33 | 54.21 | 55.01 | 54.95 | 49.93 | 1.48 |
| Egg width (mm) | 42.31 | 42.97 | 42.17 | 42.64 | 42.93 | 38.73 | 0.20 |
| Egg shape index (%) | 78.16 | 77.72 | 77.77 | 77.55 | 78.14 | 77.51 | 3.35 |
| Shell thickness (mm) | 0.65 | 0.62 | 0.65 | 0.65 | 0.67 | 0.73 | 0.02 |
| Shell wgt (g) | 5.40 | 5.40 | 5.40 | 5.50 | 5.50 | 5.60 | 1.94 |
| **Internal qualities** | | | | | | | |
| Albumen wgt (g) | 35.50 | 36.50 | 36.50 | 37.50 | 36.50 | 35.00 | 0.64 |
| Albumen hgt (mm) | 12.50 | 13.00 | 11.50 | 12.50 | 13.00 | 12.00 | 0.86 |
| Alb. dmt (mm) | 53.50 | 51.25 | 54.00 | 53.25 | 52.63 | 54.50 | 0.12 |
| Yolk wgt (g) | 14.00 | 13.25 | 12.25 | 13.00 | 13.75 | 13.00 | 0.90 |
| Yolk diameter (mm) | 42.25 | 42.00 | 39.88 | 41.63 | 40.88 | 39.38 | 0.92 |
| Yolk height (mm) | 32.75 | 32.13 | 33.38 | 32.38 | 33.75 | 34.00 | 0.58 |
| Yolk index (%) | 77.52 | 76.50 | 83.70 | 77.78 | 82.56 | 86.34 | 0.63 |
| Yolk colour | 10.75 | 11.00 | 10.75 | 11.13 | 11.63 | 11.75 | 0.63 |
| Yolk cholesterol (mg/g) | 43.95 | 43.96 | 46.33 | 47.55 | 49.67 | 51.24 | 0.01 |
| Haugh unit (HU) | 99.27 | 99.62 | 98.68 | 99.04 | 99.61 | 99.13 | 0.02 |

abc:Means on the same row having different superscript were significantly ($P<0.05$) different. SEM: Standard Error of Mean,T1: basal diet without any additive;T2: basal diet with Tylo-dox Extra WSP as antibiotics/100 kg feed; T3: Diet with 0.2% (200 g) of PNLM/ 100 kg of feed; T4: Diet with 0.3% (300 g) of PNLM/100 kg of feed; T5: Diet with 0.4% (400 g) of PNLM/100 kg of feed; T6: Diet with 0.5% (500 g) of PNLM/100 kg of feed.

Table 2 displays the average laying production parameters of the experimental birds administered *P. niruri* leaf meal as feed additive. Age and weight at first lay, weight of the first egg, and hen day egg production (total number of eggs laid by the flock in a given period divided by the product of the number of days and the number of hens alive) at weeks four, eight, and twelve of laying were the criteria taken into account. Treatment1 birds laid their first egg at 119.50 days, and T4 birds did the same at 125 days. T5 had the heaviest weight of birds at first lay (1621 g), whereas T1 had the lightest weight (1319.25 g). The highest weight of first egg was gotten from birds in T6 (46.25 g). The effects of the feed interventions on hen-day egg production were substantial ($P<0.05$). At the fourth (45.00%), eighth (76.50%), and twelfth (92.71%) weeks in lay, laying hens fed T6 (0.5% PNLM) demonstrated improved performance.

The birds in these groups may be able to attain lay at a younger age due to higher body weight at first lay. A highly important characteristic from an economic perspective is age at sexual maturity and the first year of production is determined by the pullet's age at first oviposition, The ISA Brown suggestion (126 days) offered by Hendrix Genetic Company Limited (www.HendrixGenetics.com) was older than the lowest age at first lay discovered in this study, and this difference may be due to environmental variables. Majority of livestock reproductive efficiency are studied to be significantly influenced by nutrition (Attia, 2018). Dietary intake, daily schedule of illumination, and daylight hours, and external variables are the primary drivers of weight and age at sexual maturity (Attia, 2018). The commercial layer typically begins to lay between 18 and 19 weeks (126-133 days) of age, and after that, egg production soars, reaching a peak of 94-96% (www.HendrixGenetics.com) at 26 to 27 weeks of age before progressively falling (Rahman, 2003).

The strong reproductive influence, which is evident with egg production, has an impact on age at sexual maturity as well. The most likely cause of this delay is because these organs must achieve a specific weight before they are considered sexually mature since they respond to feed distribution and are impacted by body mass index (Robbinson et al., 2007). According to Akthar, Nasir, and Abid (2013), 1.5% of black cumin seeds increased laying rates in laying hens from 40-52 weeks of age by 12%. Over the course of a 5-week investigation, black cumin seed supplementation boosted egg production and egg weight in 27-week-old laying hens compared to diets supplemented with 1% (Aydin, Karaman, Cicek & Yardibi, 2008).

*International Journal of Women in Technical Education and Employment*
*ISSN: 2811-1567. Volume 4 – Issue 1. July 2023*
*https://fpiwitedjournal.federalpolyilaro.edu.ng*

**Table 2: Effect of *P. niruri* leaf meal inclusion on production parameters of layer chicken at laying phase (day 141- 224)**

| Parameters | T1 | T2 | T3 | T4 | T5 | T6 | SEM± |
|---|---|---|---|---|---|---|---|
| Age at first lay (day) | 119.50[b] | 131.25[ab] | 132.50[a] | 125.00[ab] | 135.75[a] | 133.00[a] | 5.99 |
| Weight at first lay (g) | 1319.25[b] | 1500.00[ab] | 1487.50[ab] | 1472.00[ab] | 1621.00[a] | 1534.50[ab] | 2.02 |
| Weight of first egg (g) | 34.75[d] | 37.00[c] | 41.25[b] | 39.75[c] | 41.25[b] | 46.25[a] | 0.22 |
| **Hen day egg production (%)** | | | | | | | **SEM±** |
| 4 weeks in lay | 32.00 | 34.00 | 35.00 | 40.50 | 42.00 | 45.00[a] | 4.22 |
| 8 weeks in lay | 58.00 | 61.98 | 62.50 | 64.06 | 70.30 | 76.50[a] | 5.65 |
| 12 weeks in lay | 86.46 | 88.54 | 90.10 | 90.63 | 91.15 | 92.71 [a] | 6.21 |

abc:Means on the same row having different superscript were significantly (P<0.05) different. SEM: Standard Error of Mean,T1: basal diet without any additive;T2: basal diet with Tylo-dox Extra WSP as antibiotics/100kg feed; T3: Diet with 0.2% (200g) of PNLM/ 100kg of feed; T4: Diet with 0.3% (300g) of PNLM/100kg of feed; T5: Diet with 0.4% (400g) of PNLM/100kg of feed; T6: Diet with 0.5% (500g) of PNLM/100kg of feed.

## Discussion

The outcomes of this study's examination of the egg's exterior quality are consistent with those of Ding, Yu, Su, and Zhang (2017), who discovered that adding the commercial supplement Enviva essential oil significantly increased the eggshell's thickness but had no impact on the shell's resistance contrasted with the control group. Relative findings were made by Abdel-Wareth (2016) who discovered a similar increase in eggshell thickness in layers given 250 mg/kg thymol, as well as Karadaolu zsoy, lmez, aydin, and Ahin (2018) who noticed that laying hens' eggshell thickness significantly increased given 0.10, 0.20, or 0.30 mL/L of oregano-based essential oil. The findings of this investigation, however, contradict the report of Wang et al. (2019), that adding 450 or 300 mg/L essential oils and organic acids (100 g/kg thymol, 200 g/kg fumaric acid and 200 g/kg sorbic acid) did not influence the thickness of the shell but substantially improved its breaking strength in comparison to the control.

This study is consistent with the study of Nasiroleslami and Torki (2010) that adding herbal supplement to the diet of layers improved egg weight, shell weight, and shell thickness. Atawodi et al. (2010), also observed that antioxidant qualities of *P. niruri* leaf meal, such as its high nutritional values and leaves' abundance in minerals, vitamins, and other crucial phytochemicals, may be responsible for the increased shell thickness.

Eggs are categorized by shape index as pointed (<72), standard (between 72 and 76), and rounded (>76) according to USDA (2018). The average results at the first, fourth, eighth, and twelfth weeks of lay showed that pullets fed a control feed and diets consisting of PNLM, respectively, showed rounded format (>76). The shape index enables standardization of eggs, which improves their look and lowers losses owing to improved packaging. Then, it is feasible to draw the conclusion that the eggs produced by birds fed diets 1-6 maintained an index shape that satisfied consumer desires for this exterior quality criterion.

It is interesting to note that egg weight is significantly influenced by hen age and production intensity, as well as by genetic factors (Bolukbasi, Erhan, & Kaynar, 2018). The age of the chickens in this investigation had a significant impact on this feature. The majority of literature sources attest to the absence of impacts of plant additions on egg weight (Liu et al. 2013; Liu et al. 2014). Intriguingly, the findings published by Bolukbasi et al. (2018) shows a considerable improvement in egg weight in hens given diet combinations of 200 mg/kg of thyme oil, sage oil, and mainly rosemary oil (by 5.77, 2.12, and 7.62 g, respectively). On the other hand, hens' egg production was reduced when sweet green peppers were added to their diet (Rossi *et al*., 2015).

Inclusion of *P. niruri* leaf meal to the nutrition of layers did not give a significant improve in the weight of the yolk (P>0.05). However, compared to birds on other experimental diets, birds on diet 4 (0.3% PNLM) had a higher albumen weight. The experimental diets had no appreciable (P>0.05) impact on the Haugh unit, yolk index, or albumen height, while the addition of dietary herbs in the diet enhanced the Haugh unit and yolk index values. Result from this study agrees with the findings that the Haugh unit and the quality of the egg's components (yolk and albumen) are positively correlated (Nobakht & Mogheddam, 2012). Indicators for evaluating the Haugh unit include egg albumen height and egg weight. Egg weight growth is correlated with albumen weight growth. The key factor contributing to the improvement in the Haugh unit in this study may be an increase in egg weight brought on by weight increases in the albumen and yolk. Haugh units ranged from 98.68 in diet 3 (0.2% PNLM) to 99.62 in diet 2 in this study. The United States Department of Agriculture (USDA) classifies eggs into four categories: AA (100 to 72), A (71 to 60), B (59 to 30), and C (Below 30) (USDA, 2000). The greater the Haugh unit value, the higher the quality of the eggs.

An increase in the Haugh Unit standard is paramount for the poultry sector, given that it affects the freshness of eggs and protein quality (De Faria Domingues et al., 2016). Albumin quality can be enhanced by using phytogenic additions with antimicrobial and antioxidant capabilities, such as *P. niruri*, as previously reported by Bozkurt, Küçükyilmaz, Catli, Çınar, Bintaş & Çöven (2012) who combined a blend of phytogenic essential oils, including Oregano essential oil, to the feed of 52- to 61-week-old laying hens. Additionally, it has been demonstrated that the bioactive components in herbal plants protect the uterus and magnum as well as promote albumin secretion during laying (Abou-Elkhair, Selim, & Hussein, 2018).

Since highly pigmented yolks are more popular with customers in the market, yolk pigmentation has a significant impact on the commercialization of eggs (Roberts, 2004). For this reason, when laying hens are subjected to feed high in natural yellow/orange pigments, primarily xanthophyll, synthetic pigments, lutein, and zeaxanthin (capsanthin, citranaxanthin, cataxanthin , and cryptoxanthin), they promote various egg colouring, ranging from yellow-bright to red-dark (Albino, Carvalho, Maia & Barros, 2014). However, the yolk hue varies between lineages due to the pigments' capacity to deposit, which is connected to the birds' features of metabolism and absorption (Oliveira et al., 2014). This coloration is dependent on the solubilisation of pigments in the fat.

When PNLM was added to the diet in this study, the yolk colour score was noticeably greater than it was in the T1 and T2 groups. This might be as a result of the PNLM's primary ingredients' capacity to preserve fat-soluble substances like vitamin D and carotenoids, which are responsible for the yolk's colour (Wang et al., 2019). These findings are consistent with Wang et al.'s (2019) observation that the yolk colour of 30-week-old hens administered feed enriched with 150 or 450 mg/L essential oils and organic acids was higher than that of hens fed the control diet. In contrast, Ding et al. (2017) found no variations in yolk colour between chickens fed the control diet and those provided a boosted diet.

The outcomes demonstrated that egg yolk cholesterol levels (mg/100 g) at the end of 12th week in lay were 43.95, 43.96, 46.33, 47.55, 49.67, and 51.24, in succession. The outcome suggested that the yolk cholesterol content was significantly affected ($P<0.05$). Treatment 1 in this study has a lower cholesterol level in terms of numbers. According to Faeji, Oladunmoye, Adebayo, and Adebolu (2019), this may be as a result of *P. niruri* antioxidant content, which prevents cholesterol from forming free radicals and so holds egg yolk cholesterol in check.

## Conclusion

Laying hens fed *P. niruri* leaf meal at 0.5% exhibited higher hen-day egg production, weight of first egg laid, and yolk index than those fed the control treatment during the fourth, eighth, and twelfth weeks of lay. However, PNLM inclusion did not influence albumen proportion, egg shape index, and haugh units; therefore, adding *P. niruri* leaf meal as an additive to layers' diets is advised for increased laying output and egg quality.

## References

Abdel-Wareth, A. A. A. (2016). Effect of dietary supplementation of thymol, synbiotic and their combination on performance, egg quality and serum metabolic profile of Hy-Line Brown hens. *Britain Poultry Science*, 57(1), 114-122.

Abou-Elkhair, R., Selim, S., & Hussein, E. (2018). Effect of supplementing layer hen diet with phytogenic feed additives on laying performance, egg quality, egg lipid peroxidation and blood biochemical constituents. *Animal Nutrition*, 4(4), 394-400.

Akhtar, M. S., Nasir, Z., & Abid, A. R. (2013). Effect of feeding powdered *Nigella sativa* L. seeds on poultry egg production on their suitability for human consumption. *Vet Arch.*, 73, 181–190.

Albino, L. F. T., Carvalho, B. D., Maia, R. C., & Barros, V. R. S. M. (2014). Galinhas poedeiras: criação e alimentação. Aprenda Fácil. Performance and egg quality of commercial laying hens fed with various protected sodium butyrate. *South African Journal of Animal Science*, 50(5), 265-276.

Atawodi, S., Atawodi, J., Idakun, G., Pundstein, B., Haubner, R., Wurtele, G., Bartsch, H., & Owen, R. (2010). Evaluation of the polyphenol content and antioxidant properties of methanol extracts of the leaves, stem and root barks of *Moringa oleifera* Lam. *Journal of Medicine and Food*, 13, 710-716.

Attia, F. A. (2018). The influence of supplementing chamomile and turmeric powder on productive performance and egg quality of laying hens. *Egyptian Poultry Science*, 38 (2), 451–463.

Aydin, R., Karaman, M., Cicek, T., & Yardibi, H. (2008). Black cumin (*Nigella sativa* L.) supplementation into the diet of the laying hen positively influences egg yield parameters, shell quality and decreases egg cholesterol. *Poultry Science*, 87, 2590–2595.

Bolukbasi, S. C., Erhan, M. K., & Kaynar, O. (2018). The effect of feeding thyme, sage and rosemary on laying hen performance, cholesterol and some proteins ratio of egg yolk and *Escherichia coli* count in faeces. *Arch Geflugelkd.*, 72, 231–237.

Bozkurt, M., Küçükyilmaz, K., Catli, A.U., Çınar, M., Bintaş, E., & Çöven, F. (2012). Performance, egg quality, and immune response of laying hens fed diets supplemented with mannan-oligosaccharide or an essential oil mixture under moderate and hot environmental conditions. *Poultry Science Journal*, 91(6), 1379-1386.

De Faria Domingues, C. H., Sgavioli, S., Praes, M. F. F., Santos, E. T., Castiblanco, D. M. C., Petrolli, T. G., Duarte, K. F., & Junqueira, O. M. (2016). Lysine, methionine and cysteine digestible on performance and egg quality in laying hens: Review Pubvet., 10(6), 448-512.

Ding, X., Yu, Y., Su, Z., & Zhang, K. (2017). Effects of essential oils on performance, egg quality, nutrient digestibility and yolk fatty acid profile in laying hens. *Animal Nutrition*, 3(2), 127-131.

Duncan, D. B. (1955). Multiple Range and Multiple F-tests. Biometric: 1-42.

European Council Directive (2006). Certain marketing standards for egg grade EC 2295/2003. Brussel, Belgium.

Faeji, C. O., Oladunmoye, M. K., Adebayo, I. A., & Adebolu, T. T. (2019). Antiviral effect of *Phyllanthus amarus* leaf extract against Newcastle disease. *Asian Plant Research Journal* 2(4), 1-9.

Food and Drug Administration (2023). Nutrition Protein intake- How much protein should you eat per day, accessed on July 1st, 2023.

Karadağoğlu, Ö., Özsoy, B., Ölmez, M., Aydin, Ö.D., & Şahin, T. (2018). The effects of drinking water supplemented with essential oils on performance, egg quality and egg yolk Veterinary World, EISSN: 2231-0916 602 Available at www.veterinaryworld.org/Vol.14/March-2021/7.pdf fatty acid composition in laying hens. *Acta Vet. Eur.*, 44(2), 85-92.

Liu, H. N., Liu, L. L., Hu, Y. L., Suo, L., Zhang, F., Jin, X. A., Feng, N., Teng, Y., & Li, Y. (2014). Effect of dietary supplementation of quercetin on performance, egg quality, cecal microflora populations, and antioxidant status in laying hens. *Poultry Science*, 93: 347–353.

Liu, Y., Li, Y., Liu, H. N., Suo, Y. L., Hu, L. L., Feng, X. A., Zhang, L., & Jin, F. (2013). Effect of quercetin on performance and egg quality during the late laying period of hens. *Britain Poultry Science*, 54: 510–514.

Nasiroleslami, M., & Torki, M. (2010). Including essential oils of fennel (*Foeniculum vulgare*) and ginger (*Zingiber officinale*) to diet and evaluating performance of laying hens, white blood cell count and egg quality characteristics. *Advances in Environmental Biology*, 4: 341-345.

Nobakht, A., & Mogheddam, M. (2012). The effect of different levels of costmary (*Tanacetum balsamita*) medical plant on performance, egg traits and blood biochemical parameters of laying hens. *Iranian Journal of Animal Science*, 27: 125-130.

Oliveira, D. L., Nascimento, J. W., Camerini, N. L., Silva, R. C., Furtado, D. A., & Araujo, T. G. (2014). Desempenho e qualidade de ovos de galinhas poedeiras criadas em gaiolas enriquecidas e ambiente controlado. *Revista Brasileira de Engenharia Agrícola e Ambiental*, 18(11): 1186-1191.

Onyimonyi, A. E., Olabode, A., & Okeke, G. C. (2009). Performance and economic characteristics of broilers fed varying dietary levels of Neem leaf meal (*Azadirachta indica*). *International Journal of Poultry Science*, 8(3): 256-259.

Panda, P. C. (1996). Shape and texture of egg. In textbook on egg and poultry technology, 3rd edition, Vikas Publishing House, New Delhi, 57.

Rahman, M. (2003). Growth Poultry Industry in Bangladesh: Poverty alleviation and employment. Proceedings of the Third International Poultry Show and Seminar, February 28 to March 2, 2003, Held in Bangladesh China Friendship Conference Center (BCFCC), Sher-e-Bangla nagar, Dhaka. pp, 1-7.

Roberts, J. R. (2004). Factors affecting egg internal quality and egg shell quality in laying hens. *The Journal of Poultry Science*, 41(3): 161-177.

Rossi, P., Nunes, J. K., Rutz, F., Anciuti, M. A., Moraes, P. V. D., Takahashi, S. E., Bottega, A. L., & Dorneles, J. M. (2015). Effect of sweet green pepper on yolk colour and performance of laying hens. *Journal of Applied Poultry Research* 24:10–14.

SAS (2010). User's Guide Statistics version, 10th edition, SAS statistical package Inc., Cary, North Carolina, U.S.A.

USDA (2000). United States Department of Agriculture. Egg-grading Manual. Agricultural Handbook Number 75. Washington: Department of Agriculture, 51.

USDA (2018). United States Department of Agriculture. National nutrient database for standard reference legacy release (egg, yolk, dried), accessed on June 1st, 2018.

Wang, H., Liang, S., Li, X., Yang, X., Long, F., & Yang, X. (2019). Effects of encapsulated essential oils and organic acids on laying performance, egg quality, intestinal morphology, barrier function, and microflora count of hens during the early laying period. *Poultry Science Journal*, 98(12): 6751-6760.

Wu, G., Gunawardana, P., Bryant, M. M. & Roland, D. A. (2007). Effect of dietary energy and protein on performance, egg composition, egg solids, egg quality and profits of Hyline W-36 hens during phase 2. *International Journal of Poultry Science*, 6(1): 739-744.