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Effect of Plantago Ovata Seed Supplementation on Laying Hens' Productive Performance

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Abstract | This study was conducted at one of the fields of Al-Wardiya district in Babylon Governorate where the field experiment lasted 16 weeks, with four periods of four weeks each. This experimental field was started from 20/ 11/ 2023 to 10/ 3/ 2024 in order to study the effect of adding different levels of Plantago ovata seeds powder to the diet of laying hens on their productive performance. A total of 105 white Lohmann laying hens, 65 weeks old, were used in the experiment, and the production period was divided into four experimental periods which are (66-69) weeks, (70-73) weeks, (74-77) weeks, and (78-81) weeks of the laying hens age. The feed was provided according to the standard requirements that mentioned in the managements guide of Lohmann white layer. The laying hens were randomly distributed into five treatments (21 hens per treatment), where each treatment included three replicates with seven hens per replicate. The treatments were classified as follows: T1: a control group free of any addition, T2, T3, T4 and T5: basal feed with 10, 15, 20 and 25 gm of powdered Plantago ovata seed /kg feed respectively. The data were analyzed using a completely randomized design and the averages were compared using Duncan's multiple range test. Results showed a significant improvement ($p \leq 0.05$) in the percentage of egg production, cumulative number of eggs, egg weight, egg mass, and feed conversion factor in comparison with the control treatment. In particularly, T5 resulted in the most important outcome of this study.

Keywords | Laying hens, Plantago ovata seeds, Productive performance, Natural feed additives, Poultry nutrition, sustainable agriculture

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INTRODUCTION

The use of medicinal plants and their extracts in poultry feed has gained increasing popularity at present to ensure human health as a consumer as well as for the nutritional value of their products (Zheng *et al.*, 2019; Nihad *et al.*, 2021). In addition, the medicinal plants have a positive impact on the poultry industry due to the improvement in the overall production performance (Pliego *et al.*, 2020; Hamzah and Abdul-Lateef, 2022). On the other hand, despite the use of growth promoters and synthetic antibiotics has been common for decades in animal feed, but since 2006 their use has been banned by the European Union due to their well-known negative impacts on the animal and human health. Therefore, the scientists and specialists have been encouraged to discover suitable alternatives such as medicinal plants and herbs in recent years to feed animals (Selaledi *et al.*, 2020; Galib et al., 2023). Plantain with

its different types is an important example of these medicinal plants that can be used as feed for ruminants and poultry (Camy *et al*., 2020; Redoy *et al*., 2020) as its seeds contain many active compounds that have a wide range of beneficial effects on animal health and productivity (Yap *et al*., 2019; Nihad *et al*., 2021). The active compounds in the seeds of these plants have an important antimicrobial, antioxidant, anti-inflammatory and antiparasitic effect in broilers (Boamah *et al*., 2016; Pena-Espinoza *et al*., 2018; Hammami *et al*., 2020; Nihad *et al*., 2023). In addition, they are highly effective in removing free radicals and thus may prevent meat pigments from oxidation, which leads to improving the color and properties of meat (Redoy *et al*., 2020). Moreover, the composition of Plantago ovata seeds in particular, which are rich in fatty acids, amino acids, minerals, vitamins and other beneficial elements (Romero *et al*., 2006), improves the nutritional value of meat which supports the organic production of meat and eggs (Li *et al*., 2017; Layth and Nihad, 2023). Over the past decades, egg consumption has doubled (Zaheer, 2015; Nbras and Nihad 2023a), leading to a steady increase in demand for laying hens. However, keeping up with this increase in consumption has become a challenge, as producers suffer from a decrease in total production with the relative advancement in the age of the chicken, which results in economic losses. In addition, the digestive system of laying hens is also affected accordingly, as the weakness of the mucosal cells in the intestinal wall and the shortness of the villi lead to a decrease in the efficiency of nutrition associated with a decrease in the absorption of nutrients and a decrease in calcium and phosphorus in the bloodstream (Foley, 2021; Al-Jebory *et al*., 2024). In addition to these digestive changes, eggs also change, as the size of the egg increases with the age of the chicken, but the shell percentage does not increase, which leads to the eggshell being thinner and weaker.

Plantago Ovata seeds contain proteins, carbohydrates, fibers and fats (Romero *et al*., 2006). Many studies have indicated that Plantago Ovata seeds contain phenolic compounds (Nishib *et al*., 2001; Patel *et al*., 2016; Divani *et al*., 2018), which are considered as one of the important natural additives in animal nutrition, as the large increase in global demand for safe animal food consumption represents a major challenge for specialists in this field at present. The antioxidant activity of phenols is one of their main features. Phenols have additional benefits on immunity, anti-inflammatory, gut health and antimicrobial activity (Mahfuz *et al*., 2021; Najeh *et al*., 2023). Studies have showed an increased growth rate and an improved feed conversion when the poultry feeds containing phenolic compounds. This is attributed to the change in the surface area of the intestine as well as the increase in the activities of digestive enzymes, which in turn leads to better absorption of nutrients (Mountzouris *et al*., 2011; Viveros *et al*., 2011). Sagar *et al*. (2020) showed that the seeds of Plantago ovata contained phenolic compounds in the amount of 8.72 mg GAE/g (GAE: Gallic acid equivalent). Patel *et al*. (2016) also indicated that different parts of Plantago ovata contained phenolic compounds. Furthermore, flavonoids which are a group of natural substances with variable phenolic structures can be found in all parts of the plant (Dewick, 2001; Nbras and Nihad, 2023b). These natural products are well known for their important health-promoting effects (Burak and Imen, 1999; Ovando *et al*., 2009; Lee *et al*., 2009). Flavonoids have several subgroups, which include Chalcones, Flavones, Flavonols and Isoflavones (Panche *et al*., 2016). The use of flavonoid supplements in poultry feed has shown the potential to improve the quality and nutritional value of eggs and poultry meat (Kamboh *et al*., 2019). Previous studies showed the positive effects of flavonoid supplements in poultry and their impact on the quality of the final product. Cai *et al*. (2013) for example, showed that the use of daidzein (isoflavone) in relatively small amounts (10-100 mg/kg) in the diet of laying hens led to improved egg production as well as improved eggshell strength. On the other hand, Sagar *et al*. (2020) showed that the seeds of the Plantago ovata plant contain flavonoids in an amount of 2.11 mg CE/g (CE: Catechin equivalent). Furthermore, Patel *et al*. (2016) indicated that the different parts of the Plantago ovata plant contain flavonoids.

The Plantago ovata seeds contain a high percentage of amino acids (Romero *et al*., 2006). The use of amino acid supplements in poultry feed improved feed conversion efficiency (Beski *et al*., 2015). These seeds also contain different types of vitamins that vitamins play an important role in eliminating free radicals and improving antioxidant levels and immune functions (Sagar *et al*., 2020). The seeds of this plant are used in many countries, especially China and India to treat fever, cough, cold problems and digestive disorders as an alternative to chemical drugs such as antibiotics (Bahmani *et al*., 2016). The well-known human use of Plantago ovata seeds promote their use in poultry nutrition. Mukhtar *et al*. (2017) used planago ovata husks in feeding 70-week-old white Leghorn layers under high temperatures. The studied ratios (5, 10 and 20 g/kg) of husks did not have a significant effect on weight gain, egg production, feed intake and mortality. This may be attributed to the use of seed husk rather than the whole seeds or the extreme conditions of the study such as the high temperatures that accompanied the experiment. However, their results showed a positive effect on egg mass and shell thickness as well as a decrease in cholesterol levels in egg yolk and blood. Divani *et al*. (2018) also used Planago ovata husks in feeding broiler chickens to study their effects on productive performance, immunity and intestinal bacterial count. The results showed an increase in body weight. Mahmoud *et al*. (2022) emphasized the possibility of using Plantago ovata husks as a natural nutritional source added to poultry and animal feed, as its commercial potential can

be greatly exploited to produce eggs and organic meat and reduce cholesterol in meat, which is necessary in the future.

Table 1: Feed used in the experiment.

Materials	Concentration
Yellow corn (ground)	36.5
Wheat (%)	12
Barley (%)	12.83
Soybean (%)	25.92
Protein [1] (%)	2.5
Limestone (%)	9.25
Vegetable oil (%)	1.0
Sum. (%)	100
C Chemical composition[2]	2700
Energy (Kk/kg DM)	17
Crude protein (%)	3.68
Crude fiber (%)	4.13
Calcium (%)	0.42
Phosphorus (%)	0.71
Methionine + cysteine %	0.92
Lysine (%)	202.43
Dietary Cation-Anion Balance (mg/kg)	0.17
Choline (%)	0.54
Folic acid (mg/kg)	0.73
Glycine (%)	1.58
Glycine + serine (%)	0.45
Histidine (%)	0.71
Isoleucine (%)	1.41
Leucine (%)	0.92
Lysine (%)	0.42
Methionine (%)	0.29
Cysteine (%)	0.82
Phenylalanine (%)	0.70
Tyrosine (%)	1.52
Phenylalanine + Tyrosine (%)	0.64
Threonine (%)	0.25
Tryptophan (%)	0.80
Valine (%)	1.07
Arginine (%)	

[1]Protein concentrate from the Dutch company Profimi. Each kg contains: 5.9% crude protein, 3600 representative energy calories/kg, 6.4% calcium, 5.7% phosphorus, 6.5% sodium, 4000 mg/kg iron, 2800 mg/kg zinc, 600 mg / kg copper, 8.35 mg cobalt, 60 mg/kg iodine, 10 mg/kg selenium, 5.9% methionine, 1.5% lysine 5.9% methionine with cysteine, 1200 mg/kg niacin, 400,000 IU vitamin A, 140,000 IU vitamin D3, 2000 mg/kg E, 100 K, 90 mg/kg vitamin B1, 160 ppb vitamin B2, 200 mg/kg vitamin B6 and 1000 mg/kg vitamin B12; [2]The analysis of the entering feed materials was used to calculate the chemical composition (Amy and Nick, 2016).

While the challenges of synthetic antibiotics and aging hens are addressed by a wide range of researchers, the unique value of Plantago ovata seeds compared to other natural additives is not fully emphasized. In order to overcome these challenges and as a result of the beneficial effects of Plantago ovata seeds, the aim of this study was to investigate the effect of adding Plantago ovata seeds (as an additive) to the diet of laying hens on their productive performance. Different levels of these seeds were used and the percentage of egg production, cumulative number of eggs, egg weight, egg mass, and feed conversion factor were evaluated at four periods of four weeks each.

MATERIALS AND METHODS

This study was conducted in a field in Babylon Governorate, for the period from 11 November 2023 to 10 march 2024 (16 weeks), to study the effect of adding different levels of Plantago ovata seed powder to the feed of laying hens on the productive performance. A total 105 white Lohmann laying hens, 65 weeks old, were used in the experiment. The experiment included five treatments, each treatment included three replicates, with (7) hens in each replicate. The experimental treatments were classified as follows: T1: a control group free of any addition, T2: basal feed with 10 gm of powdered Plantago ovata seed /kg feed, T3: basal feed with 15 gm of powdered Plantago ovata seed /kg feed, T4: basal feed with 20 gm of powdered Plantago ovata seed /kg feed and T5: basal feed with 25 gm of powdered Plantago ovata seed /kg feed. The amount of feed consumed by the hens was calculated in accordance with the managements guide of Lohmann white layer as shown in Table 1.

The experiment period was divided into four production periods which are (66-69), (70-73), (74-77), and (78-81) weeks of hens age. The investigated production characteristics of laying hens included egg production rate, cumulative number of eggs, average egg weight, average egg mass, and feed conversion factor. The experimental data were analyzed using a completely randomized design (CRD) to investigate the effect of the studied treatments on the different characteristics. It is a research method where the experimental units are randomly assigned to treatments without any systematic bias. The implementation of this type of design is relatively simple in addition to its flexibility, robustness and generalizability. The averages were compared using Duncan's multiple range test (Duncan, 1955). Duncan's multiple range test compares the means of multiple groups after finding a significant difference in an analysis of variance test. The statistical program SAS (2012) was used in the statistical analysis. The following equations were used to calculate the required parameters:

$$HD\ \% = \frac{Total\ number\ of\ eggs\ produced\ during\ the\ period}{Total\ number\ of\ hens\ in\ the\ same\ period} \times 100$$

$$Average\ egg\ mass\ (g) = HD\ \% \times Average\ egg\ weight\ (g)$$

$$Feed\ Conversion\ factor\ (g\ feed/g\ eggs) = \frac{Feed\ intake\ (g)}{Egg\ production\ (g)} \times 100$$

Table 2: Effect of adding powdered Plantago ovata seed to the feed of white Lohmann laying hens on the egg production percentage (HD%) for the period of (66-81) weeks (mean ± standard error).

Treatments	First period (66-69)	Second Period (70-73)	Third Period (74-77)	Fourth period (78-81)	Average (66-81)
T1	57.14 ±2.06c	62.93 ±1.33c	64.29 ±1.29d	57.31 ±0.45c	60.42 ±0.42e
T2	56.97 ±2.74c	66.33 ±2.04bc	71.43 ±2.78c	70.52 ±3.59b	66.31 ±0.99d
T3	64.63± 1.11b	69.90 ±1.18b	77.21 ±2.95bc	74.66 ±1.34b	71.60 ±0.45c
T4	68.37± 3.71ab	76.87 ±2.13a	83.16 ±3.88ab	80.95 ±3.41a	77.34 ±0.11b
T5	75.51± 4.50a	80.10 ±3.64a	86.22 ±4.46a	85.71 ±2.06a	81.89 ±1.64a
Significant level	*	*	*	*	*

*Means there are significant differences between treatments at a significance level of (p≤0.05). T1: control (without addition); T2, T3, T4 and T5 treatments are feed with powdered plantago ovata seed added at an amount of 10, 15, 20 and 25 g/kg feed, respectively.

RESULTS AND DISCUSSION

Table 2 shows the effect of adding the Plantago ovata seeds powder to the feed of white Lohmann laying hens on the egg production rate (HD %) for the period of 66-81 weeks (mean ± standard error), The first production period (66-69 weeks) showed a significant improvement - (p≤0.05) in the results of T4 (20 g seed powder/ kg feed) and T5 (25 g seed powder/ kg feed) treatments. These treatments resulted in the highest percentage of egg production as 68.37% and 75.51% respectively, compared to T1 (control) and T2 (5 g seed powder/ kg feed) treatments, which showed the lowest HD as 57.14% and 56.97%, respectively. Meanwhile, T3 (15 g seed powder / kg feed) showed a significant improvement (p≤0.05) in comparison with T1 and T2 and did not differ significantly from T4. In the second production period (70-73 weeks), T4 and T5 continued to record the highest rates of egg production with a significant difference (p≤0.05) compared to the T1, T2 and T3 treatments. The control treatment recorded the lowest rate of egg production in this period which was 62.93%, followed by T2, which recorded 66.33%, without a significant difference from T3, which had a significant improvement (p≤0.05) in comparison with T1 (control). While during the third production period (74-77 weeks) and the fourth production period (78-81 weeks), all addition treatments (T2, T3, T4 and T5) resulted in significant improvement (p≤0.05) and recorded the highest egg production rates compared to the control treatment. The control treatment showed the lowest egg production rate of 64.92% and 57.31% during the third and the fourth periods, respectively, while T5 gave the highest egg production rate in these two periods as 86.22% and 85.71%, respectively. The average results of the four periods of the experiment (66-81 weeks) showed that the addition treatments continued to record the highest egg production rates, and T5 recorded the highest egg production rate of 81.89%, while T1 recorded the lowest egg production rate of 60.42%.

Table 3: Effect of adding the powdered plantago ovata seeds to the feed of white Lohmann laying hens on the average cumulative number of eggs (eggs/ hen/ 28 days) for the period of (66-81) weeks (mean ± standard error).

Treatments	First period (66-69)	Second Period (70-73)	Third Period (74-77)	Fourth period (78-81)	Average (66-81)
T1	16.00 ±0.58 c	17.62 ±0.37 c	18.00 ±0.36 d	16.05 ±0.13 c	16.92 ±0.12 e
T2	15.95 ±0.77 c	18.57 ±0.57 bc	20.00 ±0.22 c	19.74 ±0.17 b	18.56 ±0.28 d
T3	18.09 ±2.31 bc	19.57 ±0.33 b	21.62 ±0.26 bc	20.90 ±1.41 b	20.05 ±0.13 c
T4	19.14 ±0.76 ab	21.52 ±0.29 a	23.29 ±1.25 ab	22.67 ±0.38 a	21.66 ±0.03 b
T5	21.14 ±1.95 a	22.43 ±0.76 a	24.14 ±1.25 a	24.00 ±3.58 a	22.93 ±0.55 a
Significant level	*	*	*	*	*

*Means there are significant differences between treatments at a significance level of (p≤0.05). T1: control (without addition); T2, T3, T4 and T5 treatments are feed with powdered plantago ovata seed added at an amount of 10, 15, 20 and 25 g/kg feed, respectively.

Table 3 illustrates the effect of adding the powdered Plantago ovata seeds to the feed of white Lohmann laying hens on the average cumulative number of eggs for the period of (66-81) weeks (mean ± standard error). During the first production period (66-69 weeks), a significant superiority (p≤0.05) was observed in T4 and T5 compared to T1 and T2, which recorded the lowest averages cumulative number of eggs. The third treatment did not differ significantly neither from T1 and T2 from one side nor from T4 on the other side. During the second production period (70-73 weeks), it was observed that T4 and T5 continued to record the highest averages cumulative number of eggs, with a significant difference (p≤0.05) from T1, T2 and T3. The first treatment recorded the lowest cumulative number of eggs

of 17.62 (egg/hen/28 Day) followed by T2, while T3 was also significantly superior (p≤0.05) to T1 and did not differ significantly from T2. The results of the third production period (74-77 weeks) showed that the addition treatments (T2, T3, T4 and T5) recorded the highest rates of cumulative eggs number compared to the control treatment, which recorded the lowest rate of cumulative egg number of 18.00 eggs/hen/28 days. While in the fourth production period (78-81 weeks), the addition treatments continued to record the best rate of cumulative egg number with a significant difference (p≤0.05) compared to the control treatment. The average results of cumulative eggs number for all production periods (66-81 weeks) showed that all addition treatments recorded the best average of cumulative egg number with a significant difference (p≤0.05) from the T1. The control treatment recorded an average of cumulative egg number of 16.92 eggs/hen/28 days, while T5 resulted in the highest average of cumulative egg number of 22.93 eggs/hen/28 days.

Table 4: Effect of adding the powdered plantago ovata seeds to the feed of white Lohmann laying hens on the average egg weight (g) for the period from (66-81) weeks (mean ± standard error).

Treatments	First period (66-69)	Second Period (70-73)	Third Period (74-77)	Fourth period (78-81)	Average (66-81)
T1	70.8 3±1.07	71.22 ±0.16 d	73.00 ±0.24 c	72.78 ±0.31 c	71.96 ±0.38 c
T2	71.16 ±0.38	71.73 ±0.48 cd	73.37 ±0.27 c	73.19 ±0.21 bc	72.36 ±0.27 c
T3	71.05 ±0.80	72.34 ±0.23 bc	74.17 ±0.09 b	73.53 ±0.30 bc	72.77 ±0.26 bc
T4	71.69 ±0.92	73.29 ±0.19 ab	75.08 ±0.06 a	73.93 ±0.12 ab	73.50 ±0.19 ab
T5	72.70 ±1.29	73.59 ±0.12 a	75.12 ±0.25 a	74.47 ±0.16 a	73.97 ±0.14 a
Significant level	N.S	*	*	*	*

*Means there are significant differences between treatments at a significance level of (p≤0.05). T1: control (without addition); T2, T3, T4 and T5 treatments are feed with powdered plantago ovata seed added at an amount of 10, 15, 20 and 25 g/kg feed, respectively.

Table 4 shows the effect of adding Plantago ovata seed powder to the feed of white Lohmann laying hens on the average egg weight (g) for the period (66-81) weeks (mean ± standard error). There were no significant differences between all experimental treatments during the first production period (66-69 weeks). In the second production period (70-73 weeks), T5 recorded the highest average egg weight with a significant difference (p≤0.05) compared to T1, T2 and T3, where T1 recorded the lowest average egg weight, followed by T2. Meanwhile, T4 also had a significant improvement (p≤0.05) compared to T1 and T2. The results of the third production period (74-77 weeks) showed that the T3, T4 and T5 resulted in the best average egg weight with a significant difference (p≤0.05) compared to T1 and T2. In the fourth production period (78-81 weeks), T5 recorded the best average egg weight (74.47 g) and T1 recorded the lowest average egg weight (72.78 g). Meanwhile, T4 had a significant improvement (p≤0.05) compared to T1, which did not differ significantly from T2 and T3. The average results of the four periods (66-81 weeks) showed that T5 continued to had a significant improvement (p≤0.05) compared to T1, T2 and T3, The results showed that T5 recorded the highest average egg weight (73.97 g), while the control treatment had the lowest average egg weight (71.96 g).

Table 5: Effect of adding the powdered plantago ovata seeds to the feed of white Lohmann laying hens on the egg mass rate (g/bird/day) for the period from (66-81) weeks (mean ± standard error).

Treatments	First period (66-69)	Second Period (70-73)	Third Period (74-77)	Fourth period (78-81)	Average (66-81)
T1	40.47 ±2.05 c	44.82 ±0.96 c	46.93 ±0.85 d	41.71 ±0.42 c	43.48 ±0.35 e
T2	40.54 ±2.12 c	47.58 ±1.59 bc	52.41 ±0.76 c	51.61 ±0.55 b	48.03 ±0.85 d
T3	45.92 ±1.12 bc	50.57 ±2.00 b	57.27 ±3.72 bc	54.89 ±2.86 b	52.16 ±0.17 c
T4	49.01 ±3.41 ab	56.34 ±1.27 a	62.44 ±2.73 ab	59.85 ±1.25 a	56.91 ±0.21 b
T5	54.89 ±2.56 a	58.95 ±1.48 a	64.77 ±1.39 a	63.83 ±3.11 a	60.61 ±1.48 a
Significant level	*	*	*	*	*

*Means there are significant differences between treatments at a significance level of (p≤0.05). T1: control (without addition); T2, T3, T4 and T5 treatments are feed with powdered plantago ovata seed added at an amount of 10, 15, 20 and 25 g/kg feed, respectively.

Table 5 demonstrates the effect of adding powder Plantago ovata seeds to the feed of white Lohmann laying hens on the egg mass rate (g/bird/day) for the period (66-81 weeks) (mean ± standard error). It is noted that in the first production period (66-69 weeks), the T5 resulted in the best egg mass rate with a significant difference (p≤0.05) over T1, T2 and T3. Meanwhile, T4 had also a significant difference (p≤0.05) compared to T1 and T2, while T3 did not differ significantly from T1 and T2 from one side and T4 on the other side. The second production period (70-73 weeks) illustrated that T4 and T5 recorded the best egg mass rate compared to T1, T2 and T3, where T1 recorded the lowest

egg mass rate of 44.82 g/bird/day. The third treatment was significantly superior (p≤0.05) in egg mass rate compared to the control treatment. Regarding the results of the third (74-77 weeks) and fourth (78-81 weeks) production periods, the addition treatments recorded the best egg mass rate with a significant difference (p≤0.05) over the first treatment (control), which recorded the lowest egg mass rates. The average results of the four periods (66-81 weeks) indicate that all addition treatments recorded a significant superiority (p≤0.05) in the egg mass rate compared to the first treatment (control), which again- recorded the lowest egg mass rate of 43.48 g/bird/day, while T5 recorded the highest egg mass rate of 60.61 g/bird/day.

Table 6: Effect of adding powdered plantago ovata seeds to the feed of white Lohmann laying hens on the feed conversion factor (g feed/g eggs) (Dry matter) for the period from (66-81) weeks (mean ± standard error).

Treatments	First period (66-69)	Second Period (70-73)	Third Period (74-77)	Fourth period (78-81)	Average (66-81)
T1	2.47 ±0.12 a	2.23 ±0.06 a	2.13 ±0.05 a	2.39 ±0.07 a	2.31 ±0.02 a
T2	2.46 ±0.14 a	2.10 ±0.07 ab	1.91 ±0.03 b	1.91 ±0.02 b	2.09 ±0.05 b
T3	2.18 ±0.05 ab	1.98 ±0.04 b	1.75 ±0.02 c	1.82 ±0.04 b	1.93 ±0.03 c
T4	2.04 ±0.06 bc	1.77 ±0.05 c	1.60 ±0.06 d	1.67 ±0.07 c	1.77 ±0.05 d
T5	1.82 ±0.09 c	1.69 ±0.03 c	1.54 ±0.08 d	1.57 ±0.09 c	1.66 ±0.04 e
Significant level	*	*	*	*	*

*Means there are significant differences between treatments at a significance level of (p≤0.05). T1: control (without addition); T2, T3, T4 and T5 treatments are feed with powdered plantago ovata seed added at an amount of 10, 15, 20 and 25 g/kg feed, respectively.

Table 6 shows the effect of adding Pantago ovata powdered seeds to the feed of white Lohmann laying hens on the feed conversion factor (g feed/g eggs) for the period (66-81 weeks) (mean ± standard error). In the first production period (66-69 weeks), it is noted that, T5 showed the best feed conversion factor of 1.82 (g feed/g eggs) with a significant difference (p≤0.05) compared to T1, T2 and T3, followed by T4, which had a significant improvement (p≤0.05) in comparison with T1 and T2, recording a feed conversion factor of 2.04 (g feed/g eggs). In the second production period (70-73 weeks), T4 and T5 recorded the best feed conversion factor with a significant difference (p≤0.05) compared to T1, T2 and T3, where T1 recorded a feed conversion factor of 2.23 (g feed/g eggs). In addition, T3 recorded a significant superiority (p≤0.05) over T1 in the feed conversion factor and without a significant difference from T2. The results of the third production period (74-77 weeks) indicate that the addition treatments continued to record the best feed conversion factor compared to the first treatment (control), which recorded a feed conversion factor of 2.13 (g feed/g eggs), while T4 and T5 recorded the best feed conversion factor of 1.60 and 1.54 (g feed/g eggs), respectively. In the fourth production period (78-81 weeks), T4 and T5 recorded the best feed conversion factor compared to the T1 which recorded a feed conversion factor of 2.39 (g feed/g eggs), while T2 and T3 were also significantly superior (p≤0.05) compared to T1 (control) and recorded a feed conversion factor of 1.91 and 1.82 (g feed/g eggs) respectively. With regard to the cumulative feed conversion factor (66-81 weeks), the addition treatments (T2, T3, T4 and T5) continued to record the best cumulative feed conversion factor compared to the control treatment at a significant level (p≤0.05) which recorded 2.31 (g feed/g eggs), while T5 recorded a cumulative feed conversion factor of 1.66 g feed/egg.

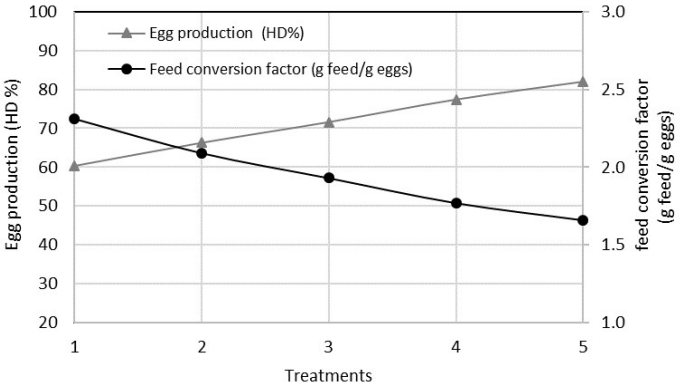

Figure 1: Variations of the egg production rate (HD %) and the feed conversion factor (g feed/g eggs) with the treatment type for the period of 66-81 weeks (average values). T1: control (without addition); T2, T3, T4 and T5 treatments are feed with powdered Plantago ovata seed added at an amount of 10, 15, 20 and 25 g/kg feed, respectively.

Figure 1 shows a more clear picture about the effect of adding Plantago ovata seeds to the feed of white Lohmann laying hens on the egg production percentage (HD %) and feed conversion factor (g feed/g eggs) for the period of (66-81) weeks. The average values of the four considered periods are illustrated in this figure. It can be seen that treatments 2, 3 4 and 5 show a clear improvement in the levels of HD in comparison with the control group (T1). The fifth treatment (25 g/kg feed) shows the highest improvement in the HD level. On the other hand, treatments 2, 3, 4 and 5 demonstrate lower feed conversion factor compared to the control treatment and also the fifth treatment gives the most important outcome.

In general, the significant improvement in the productive traits (egg production rate, cumulative number of eggs, egg

weight, egg mass and feed conversion factor) for most of the addition treatments compared to the first treatment (control) shows the importance of using Plantago ovata seeds powder in feeding laying hens. These improvements may be attributed to the seeds contain of many active compounds, including flavonoids, as illustrated previously, as flavonoids help in the improvement of the secretion of estrogen (Huo *et al*., 2020). The secretion of estrogen has an important role in improving the productive performance of laying hens, especially egg production (Akintola *et al*., 2011; Taoyan *et al*., 2023) by enhancing the secretion of follicle-stimulating hormone (FSH), which stimulates the growth, maturation and development of follicles and increases ovulation, thus increasing egg production (Prastiya *et al*., 2022). Flavonoids also play an important role in enhancing the secretion of progesterone by granulosa cells before ovulation, in addition to enhancing the proliferation and differentiation of these cells, improving the secretion of hormones and the development of ovarian follicles, which are considered safe additions to enhancing the rate of egg laying (Guo *et al*., 2020). In addition, adding Plantago ovata seeds, which have a high concentration of carotenoids (natural antioxidants) (Sagar *et al*., 2020) to poultry feed, has a positive effect on egg production rates, as antioxidants generally encourage and accelerate the release of yolk precursor from the liver to the yolk in the ovary, where they protect the membranes of hepatocytes from oxidative damage caused by free radicals. Thus, maintaining and regulating cellular metabolic functions. This leads to increasing yolk deposition in developing eggs, which results in an increase in egg mass, leading to rapid egg maturation, which is positively reflected on egg production levels (Puthpongsiriporn *et al*., 2001). In addition, the well-known role of carotenoids as anti-inflammatory agents, leads to an improvement in the physiological condition of birds, and thus is positively reflected in improving production performance, including the feed conversion factor (Sagar *et al*., 2020; Adom *et al*., 2017).

On the other hand, the reason for the improvement in the productive performance of addition treatments may be due to their containing of other active compounds, including xylo-oligosaccharides and arabinoxylan. They work synergistically in feeding and sustaining the growth of microorganisms such as lactic acid bacteria, which increase the surface area of the intestine, thus improving the digestion processes of food compounds in the feed, in addition to its physiological role in protecting the body from harmful bacteria such as coli bacilli. This role reflects the improvement directly on the productive performance of birds fed on Plantago ovata seeds (Pandey et al., 2016).

The improvement in the feed conversion factor of Plantago ovata seed treatments may be attributed to the role of phenolic compounds present in Plantago ovata seeds. These compounds play an important role in enhancing the ability of the digestive tract to digest protein and amino acids (Kaya *et al*., 2014). The reason for this improvement may be due to the antioxidants present in Plantago ovata seeds such as lycopene (Sagar *et al*., 2020) and their important role in protecting fats and unsaturated fatty acids from oxidation and rancidity by inhibiting lipid peroxidation and suppressing free radicals that attack and destroy fats and polyunsaturated fatty acids, thus causing a decrease in the nutritional value of fat and a decrease in the ability to utilize energy, as antioxidants work to prevent the separation of hydrogen atoms from unsaturated fatty acids. This process leads to preventing oxidation and lipid peroxidation, which helped to utilize the fats present in the feed as well as the energy released from fat metabolism (Brenes *et al*., 2008), which was reflected in positively on the feed conversion factor in addition treatments.

It is worth mentioning that, this study emphasized on the effect of adding Plantago ovata seeds to the diet of laying hens on their productive performance. Nevertheless, the potential effects of these seeds on the physiological or biochemical markers require a detailed investigation and the authors will address these important markers in the near future.

CONCLUSIONS AND RECOMMENDATIONS

The results of the effect of adding powdered Plantago ovata seed to the diet of white Lohmann laying hens at different levels (10, 15, 20 and 25 g/kg feed) showed an improvement in all studied productive traits. The fifth treatment, in which Plantago ovata seeds were used at a rate of 25 g/kg feed, showed the optimum productive performance with significant improvements ($p \leq 0.05$) in comparison with the control treatment. The most important improvement in this treatment was found in the egg production rate which increased from 60.42 % to 81.89% as a result of using Plantago ovata seed. This significant outcome requires further investigations on the effects of using Plantago ovata seeds at this rate on the physiological traits and oxidation indicators of the produced eggs.

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NOVELTY STATEMENT

Possibility of improving the productive performance of laying hens using Plantago ovata seeds.

AUTHOR'S CONTRIBUTIONS

All authors contributed equally for this work.

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Conflict of Interest

All authors declare that there is no conflict of interest in this study.

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