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Study of The Productive Performance of Adding Different Levels of *Chenopodium quinoa* Seeds to The Diet of Laying Hens

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ABSTRACT

The current study was implemented in a privately-owned poultry field located in Diyala Governorate and extended over a period of 12 weeks, from February 1st to April 25th, 2025. This timeframe was segmented into three equal phases, each lasting four weeks. The primary objective was to evaluate the productive performance of laying hens when supplemented with varying concentrations of Chenopodium quinoa seeds in their diet. A total of 96 Lohmann White laying hens, aged 65 weeks at the onset of the trial, were housed and observed throughout the study. The production phase was categorized into three experimental intervals: 66–69 weeks, 70–73 weeks, and 74–77 weeks of age. Feeding was carried out in accordance with the nutritional standards outlined in the Lohmann White management manual. The hens were randomly allocated into 12 pens, comprising four dietary treatments, each involving 24 birds. Every treatment was further divided into three replicates, with each replicate consisting of 8 hens. The dietary treatments were as follows: Treatment 1 (control) received no supplementation; Treatment 2 was supplemented with 15 mg of quinoa seeds per kg of feed; Treatment 3 with 30 mg/kg; and Treatment 4 with 45 mg/kg. Statistically significant enhancements ($P \leq 0.05$) were observed in Treatment 2 regarding egg production percentage, total egg count, and egg mass, when compared to the control group.

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INTRODUCTION

One of the primary challenges currently confronting the poultry sector is identifying natural alternatives to synthetic additives in both water and feed, aimed at enhancing production efficiency. This need has become particularly urgent following the European Union's decision in 2006 to prohibit the use of antibiotic growth promoters in livestock systems. Among the most promising alternatives are medicinal plants and herbs, which have long been utilized in traditional medicine for the treatment of human ailments (Fugh-Berman, 1997; Alnidawi *et al.* 2016). In response, many researchers have begun extracting active compounds from specific plants for therapeutic and nutritional applicationsMedicinal herbs have gained increased importance due to the bioactive components that have notable effects on productivity, physiological parameters, and immune responses in poultry. For instance, postulated medicinal herbs are lemongrass leaves (Al-Awadi & Al-Nadawi, 2020) and bay leaves (Ali & Al-Shuhaib, 2021), respectively, as growth promoters in animal nutrition. Hence, quinoa (Chenopodium quinoa) is chosen for the study besides having potent antioxidant activity and excellent nutritional profile. It contains several bioactive compounds, i.e., phytoecdysteroids, phytosterols, saponins, and phytic acid (Al-Anbari & Sudad, 2019), and among others, the essential fatty acids such as linoleic, oleic, and palmitic acids (Altuna et al., 2018; Alshukri *et al.* 2018). Besides, it provides important amino acids, such as tyrosine and arginine, and important minerals, such as iron, calcium, phosphorus, and zinc (Safiullah *et al.*, 2019). For quinoa, high coefficients of digestibility have also been reported to occur (Silva *et al.*, 2015; Ali *et al.* 2016). Compared to the conventional cereals, quinoa is of superior nutritional value, particularly the content of dietary fiber, which is approximately 10% a value that is markedly higher than that found in wheat (2.7%), corn (1.7%), and rice (0.4%) (Rabia J. Abbas et al.2018 ; Muhammad et al., 2021). This evidence formed the basis of the present study, which sought to establish the influence that supplementation of quinoa seeds in a layer's diet has on laying performance, oxidative stability, and various quality traits of eggs as well as on the relative body maintenance of hens. The study will also establish the best effective inclusion level of quinoa seeds in the diet upon performance and physiological variables.

MATERIALS AND METHODS

The farm used for the field trial was privately owned and located in the Diyala Governorate, where the trial extended over a 12-week period from February 1st to April 25th, 2025. The study comprised three consecutive 4-week phases held with the primary goal of evaluating the effects of different levels of Chenopodium quinoa seeds in the diet on the productive performance of laying hens. A total of 96 Lohmann White layers 65 weeks of age at the commencement of the experiment were chosen and assigned to the age intervals 66–69 weeks, 70–73 weeks, and 74–77 weeks, respectively, to make the experiment practically applicable. All birds were offered diets that met the nutrient requirements as per the Lohmann White management guide. The hens were randomly assigned into 12 pens, representing four dietary treatments with 24 birds per treatment. Each treatment was replicated three times, with 8 birds per replicate. The experimental groups were as follows: Treatment 1 served as the control and received no quinoa supplementation; Treatment 2 received 15 mg of quinoa seeds per kg of feed; Treatment 3 received 30 mg/kg; and Treatment 4 received 45 mg/kg. The parameters evaluated during the study included egg production percentage, average egg weight, cumulative egg count, total egg mass, and feed conversion ratio. A completely randomized design (CRD) was employed to analyze the effects of the dietary treatments. Mean comparisons were conducted using Duncan's multiple range test (Duncan, 1955), and data processing was performed using the SAS software package (SAS, 2012).

Table (1): Composition and Nutritional Profile of the Experimental Diets Used During the Study

feed material	Percentage(%)
Yellow corn	36.5
Wheat	12
Barley	13.9
Soybean meal (44% protein)	25
Premix	2.5
Limestone	8.3
Vegetable oil	1.8
Total	100
Chemical composition**	
Metabolic energy (kcal/kg feed)	2756.19
Crude protein (%)	17.13
Crude fiber (%)	4
Calcium (%)	2.5
Available phosphorus (%)	0.40
Methionine + cysteine (%)	0.76
Lysine (%)	0.84

Each kilogram of the premix provided: 7.9% crude protein, 2,903 kcal/kg metabolizable energy, 23.1% calcium, 3.3% phosphorus, 5.5% sodium, 2,800 ppm iron, 2,400 ppm zinc, 600 ppm copper, 8.35 mg cobalt, 80 ppm iodine, 8 ppm selenium, 2.4% methionine, 7.7 ppm methionine + cysteine, 1,350 mg niacin, 400,000 IU vitamin A, 20,000 IU vitamin D_3, 800 IU vitamin E, 80 ppm vitamin K, 40 ppm vitamin B_1, 160 ppm vitamin B_2, 160 ppm vitamin B_6, and 1,000 ppm vitamin B_{12}.The chemical composition of the feed was calculated based on nutrient values of feed ingredients as reported by NRC (1994).

RESULTS AND DISCUSSION

Table 2 presents the impact of dietary supplementation with *Chenopodium quinoa* seeds on the hen-day egg production percentage (H.D.%) of Lohmann Brown laying hens during the age period from 66 to 77 weeks (expressed as mean ± standard error). No statistically significant differences were observed among the treatments during the first production phase (66–69 weeks). However, in the second phase (70–73 weeks), hens receiving quinoa seed supplementation in Treatments 2, 3, and 4 exhibited significantly higher egg production percentages compared to the control group (Treatment 1), which recorded the lowest production rate at 62.37%.

During the third period (74–77 weeks), Treatments 2 (15 mg quinoa/kg feed) and 3 (30 mg quinoa/kg feed) showed significantly better ($P \leq 0.05$) performance than Treatment 4 (45 mg/kg), while no significant differences were detected between the control group and any of the other treatments in this phase. Regarding the overall average across the entire experimental period (66–77 weeks), Treatment 2 achieved a significantly higher egg production percentage of 76.48% compared to the control group, which recorded the lowest value of 69.75%. Meanwhile, Treatments 3 and 4 did not differ significantly from either the control or Treatment 2.

Table 2: Effect of Quinoa Seed Supplementation in the Diet of Lohmann Brown Laying Hens on Hen-Day Egg Production Percentage (H.D.%) During the Period from 66 to 77 Weeks of Age (Mean ± Standard Error)

Period / Age in weeks / Treatments	First period (69 -66)	Second Period (73 -70)	Third Period (77 -74)	The general Average (77 – 66)
First Treatment	81.09 ±4.61	62.37± 1.43 b	65.80 ±9.62 ab	69.75 ± 1.62 b
Second Treatment	78.11 ±8 .37	78.12 ±4.91 a	73.21 ±0.93 a	76.48 ±1.25 a
Third Treatment	73.94 ±3.06	73.66 ±4.38 a	68.10 ±4.88 a	71.90 ±2.78 ab
Fourth Treatment	82.73 ±5.56	75.91 ±5.23 a	57.88 ±1.82 b	72.17 ±4.39 ab
Significance Level	N.S	*	*	*

- N.S. indicates that no statistically significant differences were observed among treatments.
- * denotes significant differences between treatments at a probability level of $P \leq 0.05$.
- Treatment 1 represents the control group (unsupplemented diet), while Treatments 2, 3, and 4 refer to diets supplemented with quinoa seeds at inclusion levels of 15, 30, and 45 mg/kg feed, respectively.

Table 3 illustrates the effect of incorporating quinoa seeds into the diets of Lohmann Brown laying hens on the cumulative number of eggs produced during the period from 66 to 77 weeks of age (expressed as mean ± standard error). During the initial production phase (66–69 weeks), no statistically significant differences were observed among the experimental treatments. However, in the second phase (70–73 weeks), hens receiving quinoa supplementation (Treatments 2, 3, and 4) demonstrated a significant increase ($P \leq 0.05$) in cumulative egg production compared to the control group (Treatment 1), which exhibited the lowest performance.
In the third phase (74–77 weeks), Treatment 2 (15 mg quinoa/kg feed) showed significantly higher cumulative egg numbers than both the control group and Treatment 4 (45 mg/kg), while no significant differences were noted between Treatment 3 and the other groups. When considering the overall average across all periods (66–77 weeks), Treatment 2 again recorded a significantly higher cumulative egg production rate ($P \leq 0.05$), reaching 21.41 eggs/hen/28 days. In contrast, the control group produced the lowest number of eggs, with an average of 19.53 eggs/hen/28 days. No significant differences were found between Treatments 3 and 4 and either of the other two treatments.

Table 3: Effect of Quinoa Seed Supplementation in the Diet of Lohmann Brown Laying Hens on Cumulative Egg Number During the Period from 66 to 77 Weeks of Age (Mean ± Standard Error)

Period / Age in weeks / Treatments	First Period (69 -66)	Second Period (73 -70)	Third Period (77 -74)	The general Average (77 – 66)
First Treatment	22.70 ± 1.29	17.46± 0.40 b	18.42± 0.69 b	19.53± 0.13 b
Second Treatment	21.87 ±2.34	21.87 ±1.37 a	20.49 ±0.26 a	21.41 ±0.19 a
Third Treatment	20.70 ±2.85	20.62 ±1.22 a	19.06 ±1.63 ab	20.13 ±0.49 ab

Fourth Treatment	23.161.55 ±	21.25 ±1.36 a	16.20 ±1.51 b	20.20 ±1.23 ab
Significance Level	N.S	*	*	*

• N.S. indicates that no statistically significant differences were observed among treatments.
• * denotes significant differences between treatments at a probability level of P ≤ 0.05.
• Treatment 1 represents the control group (unsupplemented diet), while Treatments 2, 3, and 4 refer to diets supplemented with quinoa seeds at inclusion levels of 15, 30, and 45 mg/kg feed, respectively.

Table 4 presents the effect of dietary supplementation with quinoa seeds on the average egg weight (g) of Lohmann Brown laying hens throughout the experimental period (66–77 weeks of age). The statistical analysis revealed that there were no significant differences among the treatments across the entire duration of the study.

Table 4: Effect of Quinoa Seed Supplementation in the Diet of Lohmann Brown Laying Hens on Average Egg Weight (g) During the Period from 66 to 77 Weeks of Age (Mean ± Standard Error)

Period / Age in weeks / Treatments	First Period (69 -66)	Second Period (73 -70)	Third Period (77 -74)	The general Average (77 – 66)
First Treatment	64.33± 0.66	64.00± 0.57	66.33± 1.45	64.88± 0.57
Second Treatment	65.66 ±0.88	65.33 ±0.88	66.00 ±0.57	65.66 ±0.66
Third Treatment	65.33 ±0.33	66.00 ±0.57	65.00 ±0.57	65.44 ±0.88
Fourth Treatment	66.33 ±1.85	65.33 ±1.45	66.33 ±0.88	66.00 ±1.00
Significance Level	N.S	N.S	N.S	N.S

• N.S. indicates that no statistically significant differences were observed among treatments.
• * denotes significant differences between treatments at a probability level of P ≤ 0.05.
• Treatment 1 represents the control group (unsupplemented diet), while Treatments 2, 3, and 4 refer to diets supplemented with quinoa seeds at inclusion levels of 15, 30, and 45 mg/kg feed, respectively.

Table 5 illustrates the effect of quinoa seed supplementation in the diet of Lohmann Brown laying hens on average egg mass (g/bird/day) throughout the experimental period spanning 66 to 77 weeks of age (mean ± standard error). During the first production phase (66–69 weeks), no statistically significant differences were observed among the treatments. However, in the second phase (70–73 weeks), Treatments 2, 3, and 4 demonstrated a significant improvement (P ≤ 0.05) in average egg mass compared to the control group (Treatment 1), which recorded the lowest value at 91.39 g/bird/day.
In the third phase (74–77 weeks), Treatment 2 (15 mg quinoa/kg feed) showed significantly higher egg mass values than Treatment 4 (45 mg/kg), whereas no significant differences were detected between the other treatments. Regarding the overall mean across the entire study period (66–77 weeks), hens in Treatment 2 exhibited a significantly greater average egg mass (P ≤ 0.05), reaching 50.21 g/egg/day. In contrast, the control group recorded the lowest average value of 45.25 g/egg/day. No significant differences were found between Treatments 3 and 4 when compared to either the control or the second treatment.

Table 5: Effect of Quinoa Seed Supplementation in the Diet of Lohmann Brown Laying Hens on Average Egg Mass (g/bird/day) During the Period from 66 to 77 Weeks of Age (Mean ± Standard Error)

Period / Age in weeks / Treatments	First Period (69 -66)	Second Period (73 -70)	Third Period (77 -74)	The general Average (77 – 66)
First Treatment	52.16 ± 2.75	39.91± 0.56 b	43.64± 3.94 ab	45.25 ± 1.41 b
Second Treatment	51.28 ±4.96	51.03 ±2.79 a	48.31 ±0.64 a	50.21 ±0.30 a
Third Treatment	48.30 ±4.46	48.61 ±3.14 a	44.26 ±3.40 ab	47.04 ±3.03 ab
Fourth Treatment	54.87 ±7.15	49.59 ±3.98 a	38.39 ±0.89 b	47.63 ±3.30 ab
Significance Level	N.S	*	*	*

• N.S. indicates that no statistically significant differences were observed among treatments.
• * denotes significant differences between treatments at a probability level of $P \leq 0.05$.
• Treatment 1 represents the control group (unsupplemented diet), while Treatments 2, 3, and 4 refer to diets supplemented with quinoa seeds at inclusion levels of 15, 30, and 45 mg/kg feed, respectively.

Table 6 presents the effect of quinoa seed supplementation in the diet of Lohmann Brown laying hens on feed conversion ratio (g feed/g eggs) during the period from 66 to 77 weeks of age (mean ± standard error). During the first production interval (66–69 weeks), no statistically significant differences were observed among the experimental treatments. In the second interval (70–73 weeks), hens in Treatment 2 (15 mg quinoa/kg feed) exhibited a significantly improved feed conversion ratio ($P \leq 0.05$) compared to the control group, which recorded the least efficient value of 2.50 g feed/g eggs. No significant differences were detected between Treatments 3 and 4 and either of the first two treatments during this phase.
Furthermore, during the third production interval (74–77 weeks) as well as in the overall average across the entire experimental period (66–77 weeks), no significant differences were found among all treatment groups.

Table 6: Effect of Quinoa Seed Supplementation in the Diet of Lohmann Brown Laying Hens on Feed Conversion Ratio (g feed/g eggs) During the Period from 66 to 77 Weeks of Age (Mean ± Standard Error)

Period / Age in weeks / Treatments	First Period (69 -66)	Second Period (73 -70)	Third Period (77 -74)	The general Average (77 – 66)
First Treatment	2.20± 0.12	2.50± 0.03 a	2.29± 0.45	2.33± 0.31
Second Treatment	2.24 ±2.11	1.96 ±0.10 b	2.06 ±0.12	2.08 ±0.10
Third Treatment	2.38 ±0.16	2.06 ±0.13 ab	2.25 ±0.17	2.23 ±0.06
Fourth Treatment	2.09 ±0.16	2.01 ±0.27 ab	2.60 ±2.06	2.23 ±0.08
Significance Level	N.S	*	N.S	N.S

• N.S. indicates that no statistically significant differences were observed among treatments.
• * denotes significant differences between treatments at a probability level of $P \leq 0.05$.
• Treatment 1 represents the control group (unsupplemented diet), while Treatments 2, 3, and 4 refer to diets supplemented with quinoa seeds at inclusion levels of 15, 30, and 45 mg/kg feed, respectively.

The observed improvement in productive traits including egg production rate, cumulative egg number, and egg mass in the second treatment compared to the control group may be attributed to the bioactive compounds present in quinoa seeds. Notably, phenolic compounds, phytoecdysteroids, and phytosterols are known to stimulate the digestive system and enhance nutrient assimilation (Cross et al., 2007; Sarmad and Nihad ,2017). These compounds increase the secretion of digestive enzymes such as chymotrypsin, lipase, amylase, and trypsin. From enhanced bile secretion, better appetite follows by feeding more eventually translating to better feed utilization then to better growth and egg productivity. There is a direct positive correlation between digestion efficiency, body weight, and feed intake on production performance. The compounds have been reported to increase the secretion of the digestive enzymes, chymotrypsin, lipase, amylase, and trypsin. Bile secretion is enhanced, and horses have good appetite which means that they consume more feed and this leads to better utilization of the feed and consequently leads to better growth and egg productivity. The relative growth of these compounds increases the physiological efficiency of the digestive tract due to the increased secretion of digestive enzymes.

Flavonoids are compounds found in quinoa and in almost all other plant foods, with activities across the biological spectrum, including immune modulation and anti-inflammatory effects. Such activities would obviously promote better health and lower risk of disease, thus indirectly supporting higher production levels. Such bioactive compounds include quercetin, known to be an important liver function activator and metabolic performer; it is a strong anti-inflammatory and antioxidant agent. Quercetin is also known to increase nutrient utilization by the body for proteins, fats, and carbohydrates; this would also lead to better deposition of nutrients and hence better-quality eggs for the supplemented groups.

It has also been proven that quercetin positively affects the function of sex hormones, mainly estrogen hormones, which further increase secretion of FSH hormones (Artawiguna et al., 2023; Al-Jebory *et al.* 2024). Quinoa antioxidant, based on its high antioxidant power, provides a shield to preserve essential lipids and lipoproteins engaged in yolk formation, hence ensuring the availability of crucial materials for follicular development (Nazmy *et al.* 2016 ; Hakime *et al.*, 2019; Sturkie, 2021). The antioxidant regulates lipid metabolism, controlling the way fat is used by the body, and helps the follicles of the ovaries mature: all in all, this means higher reproductive performance, that is, more and heavier eggs (Anton, 2007; Menati *et al.* 2018).

CONCLUSION

The results of the present work revealed that the Chenopodium quinoa seed supplementation in the diets at 15 mg/kg feed, i.e., Treatment 2, was statistically significantly ($P<0.05$) better in improving those key productive traits of Lohmann Brown layers than the control and other treatment groups during the middle period of the experiment. Hence, it may reasonably be assumed that the positive results obtained with quinoa seeds are due to their bioactive constituents, including flavonoids, phenolic compounds, and quercetin, allowing for better utilization of nutrients by improving digestive efficiency and increasing metabolic function and also indirectly stimulating reproductive hormones. Though higher levels, i.e., 30 and 45 mg/kg, numerically performed less better, the level of 15 mg/kg joined the most optimum strength by establishing a balance between nutritional effectiveness and biological response. These findings corroborate evidence in the favor of quinoa supplementation as a natural and functional feed additive capable of enhancing poultry laying performance.

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