Effect of Green Okra Powder and Turmeric Supplementation on Laying Performance and Egg Quality Traits

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Abstract

The aim of the current research was to determine the effect of dietary supplementation on laying hens on Lohmann White hens using green okra (Abelmoschus esculentus) powder and turmeric (Curcuma longa) powder on the laying performance and egg quality traits. One hundred and forty hens at the age of 40 weeks were randomly grouped into seven treatment groups with a completely randomized design. These groups included a control and diets supplemented with 1, 2 or 3g/kg of okra or turmeric powder during 70 days.

The recorded productivity measures were based on five 14-day periods. The statistics showed that the dietary treatments had mixed effects depending on the production stage. Period 4 was associated with significant increases in the egg mass and feed conversion ratio (FCR), with the greatest increase observed in the hen fed 1g/kg okra. The percentage production of egg was significantly influenced over the period with the highest percentage obtained in the 3g/kg turmeric group.

Concerning the egg quality characteristics, the shell thickness and shell weight percentage were changed significantly in particular times particularly when the okra was supplemented. Turmeric supplementation significantly improved the yolk color score and also improved the yolk weight at specific periods. However, not all the internal egg quality parameters such as the Haugh unit and the yolk index were always influenced.

In summary, dietary supplementation with green okra and turmeric powders can reduce laying performance and certain egg quality traits in a dose- and time-dependent manner. These phytogenic supplements show potential as natural alternatives to synthetic growth promoters in laying-hen diets.

Keywords Okra, Turmeric, Egg quality, growth promoters, Yolk pigmentation

Introduction

The world poultry sector is under mounting pressure to ensure high productivity and at the same time limit the use of antibiotic growth promoters (AGP) in response to the increasing awareness with regards to antimicrobial resistance and increasing regulatory limitations. Legislative interventions led to the gradual elimination of AGPs in Europe until they were eventually not included in the register of authorised feed additives; this process increased the urgency to identify a new safe and effective alternative that would allow the maintenance of gut health, immune system, and performance, without causing any resistance In the past, antibiotic growth promoters (AGPs) were valued for their ability to reduce subclinical inflammation and modulate intestinal

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microbiota, thereby enhancing feed efficiency. Currently, however, the focus has shifted toward non-antibiotic alternatives, such as phytogenic feed additives derived from plants, to support intestinal functionality and combat oxidative stress [1, 2]. These additives contain bioactive compounds with antimicrobial and antioxidant properties, which promote immunity and have garnered increasing interest in nutrition and biomedical research [3-6]. Studies indicate that phytogenic additives can improve digestion, microbiota stability, redox status, and metabolic processes related to production and product quality in laying hens [4, 7]. Meta-analyses have shown their potential to increase egg production, enhance feed conversion, and positively modulate blood lipid profiles and oxidative stress biomarkers [8]. Due to the high metabolic rate associated with egg laying, reactive oxygen species generation increases, potentially impairing ovarian function and egg quality; therefore, phytogenic additives with antioxidant properties represent a promising nutritional intervention to improve performance and egg quality [8, 9].

Among the most commonly studied ones, in the phytogenic category, turmeric (Curcuma longa) and its main polyphenol curcumin are included. Turmeric has long been recognized as a natural alternative to antibiotic growth promoters (AGPs) due to its well-established safety profile and its diverse bioactive properties, which include antioxidant and anti-inflammatory effects [10]. Dietary turmeric powder has been cited to increase productive characteristics and improve some of the egg-quality features of hens in laying such as yolk pigmentation and interior quality indices when storing eggs [11]. Likewise, supplementing commercial layers with incremental doses of turmeric powder has been found to affect productive performance and egg quality and therefore substantiate the idea that turmeric can be considered as a functional feed ingredient in the diets of commercial layers [12]. Purified curcumin has been also taken into account along with whole turmeric as it can deliver a more standardized dose of bioactive and may act by physiological pathways (e.g. antioxidant defense, lipid metabolism).

Simultaneously, okra (Abelmoschus esculentus) is another plant resource of interest because of its nutrient composition and concentration of bioactive compounds (e.g., polyphenols, flavonoids, and other phytochemicals), which may strengthen the antioxidant capacity and metabolism. In laying hens, the effect of okra leaf meal, added at graded amounts, has been studied, whose results include the performance, egg quality, and egg lipid profiles, showing that okra-added ingredients can affect both productivity and lipid-related characteristics [16]. Although some studies on okra have been carried out in broilers, it provides some valuable biological context: dried okra fruit powder has been tested as a natural antioxidant feed supplement, with consequences on growth, blood indices, and product-quality parameters, which supports its larger prospective use as a phytogenic feed supplement in poultry nutrition [17]. All of these results make okra a potential functional feed additive that could be used to supplement the effects of other phytogenics by providing other fiber-related effects, antioxidant potential, and even lipid-modulating effects as pertains to the egg production system [16].

In the context of the modern industry trends of antibiotics-free production as well as consumer preference of high-quality and so-called functional animal products, the study of phytogenic additives in layer diets is now concentrated on the observable results, which can be important to the producer as well as to the market: egg production performance, shell quality, internal egg quality (albumen height, Haugh unit), and lipid profiles such as yolk cholesterol or serum lipid levels. The literature justifies the overall possibility that plant-based additives can enhance such results by having a combination of antimicrobial, antioxidant, anti-inflammatory, and metabolic effects [8], [7], [4].

Based on this, comparing turmeric/curcumin and okra-based supplementation either separately or in comparatively designed trials will help to add to evidence-based mechanisms of improving laying performance and egg quality and fit within the aims of antibiotic reduction.

Materials and Methods

Experimental Site and Duration.

The current study was conducted at the poultry research center of the Department of Animal Production within College of Agriculture of the University of Kirkuk, Iraq. The experiment period involved 90 days which comprised a 14 day acclimatization period during which time the subjects were allowed to adapt to the experimental diets and housing environment. Data collection began after the adaptation phase and continued through five 14 days production cycles.

Experimental birds and design

The number of employed Lohmann White laying hens was 140 (40 weeks old). The birds were baseline weighed individually and randomly assigned to seven diets based on a Completely randomized design (CRD). Every treatment was made up of five Replicates and four hens per replica.

It involved treating one control group and six experimental groups with the basal diet that lacks supplementation and with different amounts of the green okra (Abelmoschus esculentus) powder and turmeric (Curcuma longa) powder respectively. In particular: control (T1); green okra at 1, 2, and 3 g/kg diet (T2, T3, T4); turmeric at 1, 2, and 3 g/kg diet (T5, T6, T7).

Housing and Management

the hens were in vertical battery cages having four levels; each cage was 48×45×40 cm and had two birds. The feeders were installed manually and ad libitum water was provided through the nipple drinkers that were connected to a 1000 liter tank.

The light program was 16 h of light and 8 h of darkness every day throughout the experimental time. The temperature in the air was kept at 18 C° - 22 C° and the Relative humidity of 50-60%. The feed was provided at a rate of 120 g per hen per day and no restriction on access to clean water was given.

Feed additives and experimental Diets.

The basal dieting was designed to satisfy or even surpass the nutrient needs of laying hens as NRC (1994). It contained wheat, yellow corn, soybean meal, barley, vegetable oil, limestone, dicalcium phosphate, methionine, premix, salt and choline chloride.

Green okra fruits were dried in the oven and ground before being used to supplement the diet at given amounts. The turmeric powder was obtained commercially and it was then thoroughly mixed with the basal diet to ensure even distribution.

Performance Measures.

productive performance measures that were measured over five 14-day intervals.

Eggs were sampled on a daily basis at 14:00 h and the percentage hen-day egg production was calculated as follows:

H.D % = Number of eggs / Number of hens ×100 egg mass was determined twice a week with the use of a digital electronic balance (precision 0.01 g). The egg mass was calculated by dividing the percentage of egg production by the average egg weight (g) and dividing it by 100. The ratio of feed intake divided by egg mass produced was calculated to obtain the feed conversion ratio (FCR).

Final body weight was obtained at the end of the experiment by measuring body weight before and after the experiment using precision electronic scale.

Egg Quality Measurements

Five eggs per treatment (1 eggs per replicate) were randomly sampled every two weeks to assess egg-quality after 24 h of storage at room temperature.

The external quality parameters included the weight of the egg, shape index, shell thickness and percentage shell weight. The height and width of eggs were determined by using a digital caliper; shape index was determined as (egg width / egg length) x 100. Three loci (air cell, equator, sharp end) were measured with a micrometer and an average value obtained. The percentage of shell weight was estimated as (dry shell weight/ total egg weight) × 100.

Parameters of internal quality included the yolk height, yolk diameter, yolk index, albumen height, Haugh unit, yolk colour score, yolk weight and albumen weight. The measurement of yolk height and albumen height was done by use of a tripod micrometer. The diameter of the yolk was measured using a digital caliper. The yolk height was divided by the yolk diameter to get the yolk index. Haugh unit was calculated as per the equation:

H being height of albumen (mm) and W being weight of egg (g).

The Roche Color Fan was used to grade the yolk color (scale 1-15, 1 = light yellow, 15 = deep orange). The weights of the yolk and albumen were determined using a digital balance (precision 0.01gr).

Statistical Analysis

The statistical analysis of all the data was done using SPSS software [18] in a completely randomized design (CRD) and Duncan Multiple range Test was adapted to compare treatment means at the significance level of P = 0.05 [19].

Results and Discussion

1. Productive Performance

Table 1-5 show the productive performance of laying hens fed diets given during test periods with added green okra powder or turmeric.

Period 1 (2 weeks)

The dietary supplementation with okra powder or turmeric did not have any statistically significant impact on body weight or egg weight as compared to control group during first experimental period. Egg mass, however, greatly influenced by dietary treatments (P= 0.0233). Hens that received turmeric 1g/kg (T5) had the highest egg mass, 56.00 g /hen/day, and the lowest egg masses were found in the okra (T2) and turmeric (T7) groups. Feed conversion ratio (FCR) was significantly better (P = 0.0284) in hens fed with turmeric (T5) and okra (T4) at 1g/kg and 3g/kg, respectively. There was a tendency of difference in the percentage of egg production among treatments though it was not statistically significant (P = 0.0526).

Period 2 (15/9–28/9/2025)

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During the second period, no significant differences (P that exceeds 0.05) were observed in situations concerning treatments in relation to egg weight, egg production percentage, egg mass or FCR. These findings are indicative that the okra and turmeric supplementation did not significantly affect productive performance at this point of the experiment.

Period 3 (29/9–12/10/2025)

In the third period, the dietary treatments did not have any effect on the egg weight, egg production and egg mass (P> 0.05). Nevertheless, hens receiving 2g/kg okra (T3) and turmeric (T6, T7) demonstrated a significantly better FCR (P=0.0920).

Period 4 (13/10–26/10/2025)

The most dramatic treatment effects were found in the fourth period. There was a significant difference in percentage of egg production among the treatments (P=0.0386) with the 1g/kg turmeric group (T5) registering the lowest percentage (82.86) Compare with control group and other treatment. The treatments were also found to have a significant effect on the egg mass (P=. 0001) with the 1g/kg okra group (T2) recording the highest egg mass (63.54 g/ hen day), and the 1g/kg and 2g/kg turmeric groups (T5, T6) having the lowest egg masses. In addition, FCR also improved (P = 0.0005), and the best FCR was found in the 1g/kg okra group (T2; 1.89), then 3g/kg turmeric group (T7; 2.03).

Period 5 (27/10–9/11/2025)

During the last experimental period, no significant difference (P>0.05) was found in the egg weight, egg production, egg mass, and FCR between the treatments. These results suggest that the impact of okra and turmeric supplementation on the productive performance was not very constant in a longitudinal manner, but rather more apparent in the fourth period.

2. Egg Quality Features.

Tables 6-10 give the egg quality traits of laying hens that are given diets with green okra powder and turmeric supplements.

Period 1 (1/9–14/9/2025)

The dietary treatment did not have any significant effect on the egg weight and shape, shell thickness, shell weight percentage, yolk index, albumen weight, and Haugh unit during the first period (P >0.05). Supplementation, however, had a significant impact on yolk color score (P=0.0273). The maximum score of yolk color was obtained with the 2g/kg turmeric (T6) and 2g/kg okra(T3) groups with the least score being obtained in the control and 3g/kg okra groups. The yolk weight also presented significant differences amongst the treatments (P=0.0285), whereby the turmeric treatment of 1g/kg (T5) had the highest yolk weight.

Period 2 (15/9–28/9/2025)

Shape index was also a significant factor in the second period, where the dietary treatments had a significant influence (P= 0.0133), the 1g/kg okra group (T2) recorded the lowest of all groups in comparison to the control and other treatments. The percentage of shell weight and shell thickness also showed a significant effect (P = 0.0122 and P = 0.0004 respectively) with the okra - supplemented groups showing higher values compared to the control. The difference between Haugh unit was quite large (P=0.0971), with the 3g/kg okra (T4) having the greatest value. The remaining internal egg quality characteristics were not affected such as yolk index, yolk color, albumen weight and yolk weight (P>0.05).

Period 3 (29/9–12/10/2025)

In the third period, dietary supplementation did not significantly affect most of the egg quality traits (P>0.05). However, the percentage of shell weight was significantly influenced (P=0.0233) with the percentage of shell weight in the 1g/kg okra group (T2), 3g/kg okra group (T4) being numerically higher than the 1g/kg turmeric group (T5), which represents the lowest value.

Period 4 (13/10–26/10/2025)

During the fourth period, the shell thickness was significantly affected to the dietary treatments (P < 0.0001). The greatest shell thickness was found in the control group and 3g/kg turmeric group 3ℕg kg -1 turmeric group, with the least values falling in the 2g/kg and 1g/kg turmeric groups. It also had a significant influence on the yolk color score (P = 0.0357) where the 1g/kg and 2g/kg groups of turmeric had higher yolk pigmentation than the other treatments. The rest of the egg quality characteristics, i.e., egg weight, shape index, shell weight percentage, yolk index, albumen weight, yolk weight and Haugh unit, were not significantly different among treatments (P > 0.05).

Period 5 (27/10–9/11/2025)

Turmeric was found that yolk weight was influenced significantly (P= 0.0423) with yolk weight in the 1g/kg turmeric group (T5) the highest one compared to the control and the okra treatment. There were no significant impacts on other parameters of egg quality (P > 0.05).

Overall Observation

During the experimental periods, the dietary supplementation using green okra powder and turmeric showed inconsistent impacts on laying performance and egg quality. It was found that considerable increase in the mass of eggs and the feed ratio was achieved mainly in Period 4 especially when hens were fed 1g kg -1 of okra. Supplementation in the characteristics of quality of eggs had an effect on the yolk pigmentation, shell traits, and yolk weight at particular stages of production, indicating that both additives could be used to increase specific parameters of egg quality depending on the level of supplementation and stage of production.

Table 1. Productive performance of laying hens fed diets supplemented with green okra powder and turmeric during Period 1 . (1/9–14/9/2025).

Treatment	Body weight (g)	Egg weight (g)	Egg production (%)	Egg mass (g/hen/day)	FCR
T1 (Control)	1431.00 ± 31.41ᵃ	58.94 ± 5.58ᵃ	88.93 ± 3.87ᵃ	52.41 ± 2.28ᵃ	2.29 ± 0.10ᵃ
T2 (Okra 1 g/kg)	1436.80 ± 51.84ᵃ	61.14 ± 2.75ᵃ	80.71 ± 4.79ᵇ	49.35 ± 2.93ᵇ	2.44 ± 0.15ᵃ
T3 (Okra 2 g/kg)	1448.60 ± 54.40ᵃ	60.36 ± 2.41ᵃ	86.07 ± 5.27ᵃ	51.95 ± 3.18ᵇ	2.32 ± 0.13ᵃ
T4 (Okra 3 g/kg)	1435.80 ± 65.25ᵃ	63.62 ± 4.75ᵃ	84.29 ± 6.96ᵃ	53.62 ± 4.43ᵃ	2.25 ± 0.18ᵇ
T5 (Turmeric 1 g/kg)	1432.20 ± 43.16ᵃ	64.26 ± 7.63ᵃ	87.14 ± 1.50ᵃ	56.00 ± 0.96ᵃ	2.14 ± 0.04ᵇ
T6 (Turmeric 2 g/kg)	1446.20 ± 67.87ᵃ	61.72 ± 4.16ᵃ	83.21 ± 4.48ᵃ	51.36 ± 2.76ᵇ	2.34 ± 0.13ᵃ

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Treatment	Body weight (g)	Egg weight (g)	Egg production (%)	Egg mass (g/hen/day)	FCR
T7 (Turmeric 3 g/kg)	1473.00 ± 46.29[a]	63.06 ± 7.75[a]	81.07 ± 0.97[b]	51.12 ± 0.61[b]	2.35 ± 0.03[a]
ANOVA (P-value)	**0.8815**	**0.7110**	**0.0526**	**0.0233**	**0.0284**

Notes; Values are expressed as **Mean ± SD**. Means within the same column with different letters (a, b) differ significantly at **P ≤ 0.05**.

Table 2. Egg production performance of laying hens fed diets supplemented with green okra powder and turmeric during Period 2.2025/9/28–9/15)).

Treatment	Egg weight (g)	Egg production (%)	Egg mass (g/hen/day)	FCR
T1 (Control)	59.66 ± 1.40[a]	86.79 ± 4.30[a]	51.78 ± 2.57[a]	2.32 ± 0.11[a]
T2 (Okra 1 g/kg)	62.08 ± 6.19[a]	81.07 ± 8.62[a]	50.33 ± 5.35[a]	2.41 ± 0.27[a]
T3 (Okra 2 g/kg)	61.62 ± 3.37[a]	85.36 ± 5.84[a]	52.60 ± 3.60[a]	2.29 ± 0.16[a]
T4 (Okra 3 g/kg)	59.32 ± 1.66[a]	83.93 ± 4.37[a]	49.79 ± 2.59[a]	2.42 ± 0.13[a]
T5 (Turmeric 1 g/kg)	62.08 ± 7.95[a]	84.64 ± 4.82[a]	52.55 ± 2.99[a]	2.29 ± 0.14[a]
T6 (Turmeric 2 g/kg)	63.78 ± 4.22[a]	85.00 ± 3.70[a]	54.21 ± 2.36[a]	2.22 ± 0.09[a]
T7 (Turmeric 3 g/kg)	60.32 ± 2.82[a]	84.29 ± 3.66[a]	50.84 ± 2.21[a]	2.36 ± 0.11[a]
ANOVA (P-value)	**0.7192**	**0.7700**	**0.3829**	**0.4134**

Notes; Values are expressed as **Mean ± SD**. Means within the same column with different letters differ significantly at **P ≤ 0.05**.

Table 3. Egg production performance of laying hens fed diets supplemented with green okra powder and turmeric during Period 3 (29/9–12/10/2025).

Treatment	Egg weight (g)	Egg production (%)	Egg mass (g/hen/day)	FCR
T1 (Control)	65.12 ± 4.85[a]	81.43 ± 5.73[a]	53.03 ± 3.73[a]	2.27 ± 0.16[a]
T2 (Okra 1 g/kg)	65.54 ± 4.17[a]	81.43 ± 3.24[a]	53.37 ± 2.12[a]	2.25 ± 0.09[a]
T3 (Okra 2 g/kg)	62.82 ± 2.90[a]	87.14 ± 4.62[a]	54.74 ± 2.90[a]	2.20 ± 0.12[b]
T4 (Okra 3 g/kg)	62.58 ± 1.16[a]	82.86 ± 5.15[a]	52.66 ± 3.27[a]	2.29 ± 0.14[a]
T5 (Turmeric 1 g/kg)	61.78 ± 7.74[a]	81.07 ± 4.30[a]	50.09 ± 2.66[b]	2.40 ± 0.13[a]
T6 (Turmeric 2 g/kg)	67.24 ± 1.98[a]	82.50 ± 3.19[a]	55.47 ± 2.15[a]	2.17 ± 0.08[b]
T7 (Turmeric 3 g/kg)	63.30 ± 6.89[a]	85.36 ± 3.43[a]	54.03 ± 2.17[a]	2.22 ± 0.09[b]
ANOVA (P-value)	**0.5902**	**0.2500**	**0.1056**	**0.0920**

Notes: Values are expressed as **Mean ± SD**. Means within the same column with different letters differ significantly at **P ≤ 0.05**.

Table 4. Egg production performance of laying hens fed diets supplemented with green okra powder and turmeric during Period 4 (13/10–26/10/2025).

Treatment	Egg weight (g)	Egg production (%)	Egg mass (g/hen/day)	FCR
T1 (Control)	63.16 ± 4.15[a]	89.65 ± 0.80[a]	56.62 ± 0.50[b]	2.12 ± 0.02[a]
T2 (Okra 1 g/kg)	70.60 ± 14.13[a]	90.00 ± 3.24[a]	63.54 ± 2.29[a]	1.89 ± 0.07[c]
T3 (Okra 2 g/kg)	62.46 ± 3.04[a]	89.65 ± 1.96[a]	55.99 ± 1.22[b]	2.14 ± 0.05[a]
T4 (Okra 3 g/kg)	63.72 ± 2.39[a]	90.00 ± 6.13[a]	57.35 ± 3.91[b]	2.10 ± 0.14[a]
T5 (Turmeric 1 g/kg)	65.10 ± 3.11[a]	82.86 ± 6.76[b]	53.94 ± 4.40[c]	2.24 ± 0.19[a]
T6 (Turmeric 2 g/kg)	61.02 ± 2.01[b]	90.00 ± 3.91[a]	54.92 ± 2.39[c]	2.19 ± 0.10[a]
T7 (Turmeric 3 g/kg)	63.62 ± 1.05[a]	92.86 ± 3.34[a]	59.08 ± 2.13[b]	2.03 ± 0.07[b]
ANOVA (P-value)	**0.2741**	**0.0386**	**0.0001**	**0.0005**

Notes; Values are expressed as **Mean ± SD**. Means within the same column with different letters differ significantly at **P ≤ 0.05**.

Table 5. Egg production performance of laying hens fed diets supplemented with green okra powder and turmeric during Period 5 (27/10–9/11/2025).

Treatment	Egg weight (g)	Egg production (%)	Egg mass (g/hen/day)	FCR
T1 (Control)	64.02 ± 3.92[a]	87.86 ± 6.49[a]	56.25 ± 4.15[a]	2.14 ± 0.16[a]
T2 (Okra 1 g/kg)	63.48 ± 5.25[a]	86.78 ± 5.87[a]	55.09 ± 3.73[a]	2.19 ± 0.14[a]
T3 (Okra 2 g/kg)	63.18 ± 4.72[a]	86.78 ± 6.26[a]	54.83 ± 3.96[a]	2.20 ± 0.16[a]
T4 (Okra 3 g/kg)	65.16 ± 2.98[a]	84.64 ± 4.30[a]	55.15 ± 2.80[a]	2.18 ± 0.11[a]
T5 (Turmeric 1 g/kg)	65.30 ± 6.25[a]	88.93 ± 5.84[a]	58.07 ± 3.81[a]	2.07 ± 0.14[a]
T6 (Turmeric 2 g/kg)	65.90 ± 4.31[a]	87.14 ± 4.26[a]	57.43 ± 2.81[a]	2.09 ± 0.11[a]
T7 (Turmeric 3 g/kg)	62.66 ± 4.08[a]	87.50 ± 3.34[a]	54.83 ± 2.09[a]	2.19 ± 0.09[a]
ANOVA (P-value)	**0.9024**	**0.9294**	**0.6052**	**0.6330**

Notes; Values are expressed as **Mean ± SD**. Means within the same column with different letters differ significantly at **P ≤ 0.05**.

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Table 6. Egg quality characteristics of eggs produced from laying hens fed diets supplemented with green okra powder and turmeric during Period 1 (1/9–14/9/2025).

Treatment	Egg weight (g)	Shape index (%)	Shell thickness (mm)	Shell weight (%)	Yolk index	Yolk color score	Albumen weight (g)	Yolk weight (g)	Haugh unit
T1 (Control)	58.94 ± 5.58^{a}	74.44 ± 1.84^{a}	0.40 ± 0.03^{a}	9.29 ± 0.33^{a}	0.50 ± 0.03^{a}	5.00 ± 1.00^{b}	35.82 ± 4.54^{a}	15.40 ± 0.73^{b}	97.28 ± 5.33^{a}
T2 (Okra 1 g/kg)	61.14 ± 2.75^{a}	77.64 ± 4.91^{a}	0.41 ± 0.04^{a}	9.46 ± 1.20^{a}	0.49 ± 0.02^{a}	5.20 ± 0.45^{b}	36.47 ± 2.49^{a}	16.52 ± 0.90^{a}	99.09 ± 4.76^{a}
T3 (Okra 2 g/kg)	60.36 ± 2.41^{a}	75.83 ± 3.89^{a}	0.44 ± 0.04^{a}	9.75 ± 0.90^{a}	0.50 ± 0.02^{a}	6.00 ± 0.71^{a}	35.22 ± 1.11^{a}	16.44 ± 1.20^{a}	100.15 ± 7.53^{a}
T4 (Okra 3 g/kg)	63.62 ± 4.75^{a}	76.07 ± 2.19^{a}	0.41 ± 0.03^{a}	9.43 ± 0.26^{a}	0.51 ± 0.02^{a}	4.80 ± 0.84^{b}	38.66 ± 3.36^{a}	16.12 ± 1.18^{a}	103.97 ± 4.80^{a}
T5 (Turmeric 1 g/kg)	64.26 ± 7.63^{a}	75.79 ± 3.17^{a}	0.39 ± 0.03^{a}	9.63 ± 0.90^{a}	0.49 ± 0.03^{a}	6.00 ± 0.00^{a}	38.14 ± 6.07^{a}	17.16 ± 1.27^{a}	98.85 ± 3.62^{a}
T6 (Turmeric 2 g/kg)	61.72 ± 4.16^{a}	75.33 ± 1.87^{a}	0.43 ± 0.05^{a}	10.15 ± 0.97^{a}	0.49 ± 0.03^{a}	6.20 ± 0.45^{a}	36.40 ± 2.93^{a}	16.52 ± 0.69^{a}	102.29 ± 4.71^{a}
T7 (Turmeric 3 g/kg)	63.06 ± 7.75^{a}	73.79 ± 1.86^{a}	0.42 ± 0.02^{a}	9.26 ± 0.69^{a}	0.51 ± 0.02^{a}	5.40 ± 0.55^{b}	38.42 ± 6.86^{a}	16.02 ± 1.10^{a}	101.08 ± 5.46^{a}
ANOVA (P-value)	**0.7110**	**0.5877**	**0.3220**	**0.4144**	**0.5872**	**0.0273**	**0.7553**	**0.0285**	**0.3546**

Notes; Values are expressed as **Mean ± SD**. Means within the same column with different letters differ significantly at **P ≤ 0.05**.

Table 7. Egg quality characteristics of eggs produced from laying hens fed diets supplemented with green okra powder and turmeric during Period 2 (15/9–28/9/2025).

Treatment	Egg weight (g)	Shape index (%)	Shell thickness (mm)	Shell weight (%)	Yolk index	Yolk color score	Albumen weight (g)	Yolk weight (g)	Haugh unit
T1 (Control)	59.66 ± 1.40^{a}	75.52 ± 2.50^{a}	0.50 ± 1.41^{b}	7.02 ± 1.60^{b}	0.47 ± 0.03^{a}	5.00 ± 0.00^{a}	36.95 ± 1.85^{a}	16.50 ± 1.05^{a}	98.56 ± 4.30^{a}
T2 (Okra 1 g/kg)	62.08 ± 6.19^{a}	70.11 ± 4.23^{b}	3.40 ± 1.56^{a}	9.49 ± 0.75^{a}	0.47 ± 0.04^{a}	5.00 ± 0.00^{a}	37.68 ± 3.99^{a}	16.02 ± 1.42^{a}	97.48 ± 2.20^{a}
T3 (Okra 2 g/kg)	61.62 ± 3.37^{a}	73.32 ± 3.68^{a}	3.26 ± 1.04^{a}	10.35 ± 0.74^{a}	0.45 ± 0.03^{a}	5.40 ± 0.55^{a}	36.88 ± 3.60^{a}	15.60 ± 1.33^{a}	94.13 ± 5.14^{b}
T4 (Okra 3	59.32 ±	76.61 ±	3.19 ±	10.25 ±	0.47 ±	5.20 ±	33.70 ±	16.50 ±	102.07

ISSN 2072-3857

Treatment	Egg weight (g)	Shape index (%)	Shell thickness (mm)	Shell weight (%)	Yolk index	Yolk color score	Albumen weight (g)	Yolk weight (g)	Haugh unit
g/kg)	1.66[a]	2.07[a]	1.56[a]	0.36[a]	0.02[a]	0.45[a]	1.55[a]	0.71[a]	± 3.13[a]
T5 (Turmeric 1 g/kg)	62.08 ± 7.95[a]	76.41 ± 1.52[a]	2.86 ± 1.28[a]	9.28 ± 0.95[a]	0.47 ± 0.03[a]	5.00 ± 0.00[a]	37.42 ± 6.51[a]	16.40 ± 0.70[a]	100.48 ± 3.08[a]
T6 (Turmeric 2 g/kg)	63.78 ± 4.22[a]	74.55 ± 2.63[a]	3.06 ± 0.84[a]	10.15 ± 1.38[a]	0.47 ± 0.02[a]	5.00 ± 0.00[a]	38.10 ± 4.71[a]	16.82 ± 0.50[a]	98.62 ± 5.28[a]
T7 (Turmeric 3 g/kg)	60.32 ± 2.82[a]	75.66 ± 1.78[a]	2.93 ± 0.48[a]	9.73 ± 1.03[a]	0.45 ± 0.01[a]	5.20 ± 0.45[a]	35.20 ± 2.25[a]	16.70 ± 0.90[a]	97.29 ± 3.71[a]
ANOVA (P-value)	**0.7192**	**0.0133**	**0.0122**	**0.0004**	**0.8944**	**0.3172**	**0.5645**	**0.5110**	**0.0971**

Notes; Values are expressed as **Mean ± SD**. Means within the same column with different letters differ significantly at **P ≤ 0.05**.

Table 8. Egg quality characteristics of eggs produced from laying hens fed diets supplemented with green okra powder and turmeric during Period 3 (29/9–12/10/2025).

Treatment	Egg weight (g)	Shape index (%)	Shell thickness (mm)	Shell weight (%)	Yolk index	Yolk color score	Albumen weight (g)	Yolk weight (g)	Haugh unit
T1 (Control)	65.12 ± 4.85[a]	74.81 ± 2.51[a]	0.43 ± 0.01[a]	9.90 ± 0.40[a]	0.48 ± 0.01[a]	5.20 ± 0.45[a]	37.94 ± 4.13[a]	17.22 ± 1.07[a]	103.26 ± 6.23[a]
T2 (Okra 1 g/kg)	65.54 ± 4.17[a]	76.51 ± 2.39[a]	0.41 ± 0.04[a]	10.79 ± 0.71[a]	0.48 ± 0.04[a]	4.80 ± 0.45[a]	38.14 ± 3.01[a]	17.74 ± 1.12[a]	98.74 ± 2.00[a]
T3 (Okra 2 g/kg)	62.82 ± 2.90[a]	74.32 ± 2.35[a]	0.44 ± 0.02[a]	10.12 ± 0.74[a]	0.48 ± 0.03[a]	4.60 ± 1.14[b]	36.48 ± 2.44[a]	17.58 ± 1.44[a]	98.13 ± 2.01[a]
T4 (Okra 3 g/kg)	62.58 ± 1.16[a]	77.37 ± 1.08[a]	0.42 ± 0.03[a]	10.93 ± 0.84[a]	0.48 ± 0.01[a]	5.00 ± 0.71[a]	37.36 ± 3.61[a]	16.82 ± 0.81[a]	102.67 ± 2.79[a]
T5 (Turmeric 1 g/kg)	61.78 ± 7.74[a]	75.22 ± 2.62[a]	0.39 ± 0.07[b]	8.55 ± 1.84[b]	0.47 ± 0.03[a]	5.00 ± 0.71[a]	37.58 ± 5.17[a]	16.74 ± 1.49[a]	100.24 ± 3.60[a]
T6 (Turmeric 2 g/kg)	67.24 ± 1.98[a]	74.58 ± 2.75[a]	0.42 ± 0.03[a]	10.08 ± 1.26[a]	0.47 ± 0.01[a]	5.20 ± 0.45[a]	40.52 ± 2.71[a]	16.96 ± 0.70[a]	99.80 ± 2.33[a]
T7 (Turmeric 3 g/kg)	63.30 ± 6.89[a]	74.65 ± 3.04[a]	0.44 ± 0.04[a]	10.42 ± 0.71[a]	0.48 ± 0.01[a]	5.60 ± 0.55[a]	36.04 ± 6.17[a]	17.58 ± 0.59[a]	100.57 ± 4.20[a]

ISSN 2072-3857

Treatment	Egg weight (g)	Shape index (%)	Shell thickness (mm)	Shell weight (%)	Yolk index	Yolk color score	Albumen weight (g)	Yolk weight (g)	Haugh unit
ANOVA (P-value)	**0.5902**	**0.3950**	**0.3359**	**0.0233**	**0.8735**	**0.3735**	**0.7082**	**0.6515**	**0.2538**

Notes; Values are expressed as **Mean ± SD**. Means within the same column with different letters differ significantly at **P ≤ 0.05**.

Table 9. Egg quality characteristics of eggs produced from laying hens fed diets supplemented with green okra powder and turmeric during Period 4 (13/10–26/10/2025).

Treatment	Egg weight (g)	Shape index (%)	Shell thickness (mm)	Shell weight (%)	Yolk index	Yolk color score	Albumen weight (g)	Yolk weight (g)	Haugh unit
T1 (Control)	63.16 ± 4.15[a]	75.95 ± 2.48[a]	0.44 ± 0.01[a]	9.46 ± 0.42[a]	0.49 ± 0.01[a]	5.20 ± 0.45[b]	37.60 ± 3.34[b]	16.92 ± 1.24[a]	100.02 ± 4.59[a]
T2 (Okra 1 g/kg)	70.60 ± 14.13[a]	75.96 ± 1.39[a]	0.39 ± 0.01[b]	8.73 ± 1.62[b]	0.47 ± 0.03[a]	5.20 ± 0.45[b]	45.16 ± 13.10[a]	17.22 ± 1.61[a]	97.95 ± 1.80[b]
T3 (Okra 2 g/kg)	62.46 ± 3.04[a]	74.96 ± 0.88[a]	0.39 ± 0.02[b]	10.12 ± 0.56[a]	0.47 ± 0.01[a]	5.20 ± 0.45[b]	36.54 ± 2.24[b]	16.70 ± 0.49[a]	102.30 ± 4.15[a]
T4 (Okra 3 g/kg)	63.72 ± 2.39[a]	75.56 ± 2.71[a]	0.36 ± 0.01[c]	9.47 ± 0.95[a]	0.46 ± 0.01[b]	5.20 ± 0.45[b]	37.56 ± 2.45[b]	17.26 ± 0.47[a]	100.54 ± 3.03[a]
T5 (Turmeric 1 g/kg)	65.10 ± 3.11[a]	76.99 ± 1.79[a]	0.35 ± 0.02[c]	9.34 ± 0.34[a]	0.45 ± 0.01[b]	6.00 ± 0.00[a]	39.18 ± 2.43[a]	17.12 ± 0.79[a]	99.46 ± 1.47[a]
T6 (Turmeric 2 g/kg)	61.02 ± 2.01[b]	77.49 ± 1.02[a]	0.32 ± 0.03[d]	9.07 ± 0.45[a]	0.46 ± 0.02[b]	5.60 ± 0.55[a]	35.92 ± 0.89[b]	16.98 ± 1.21[a]	99.34 ± 4.37[a]
T7 (Turmeric 3 g/kg)	63.62 ± 1.05[a]	76.41 ± 1.68[a]	0.43 ± 0.01[a]	9.68 ± 0.91[a]	0.46 ± 0.03[b]	5.20 ± 0.45[b]	36.50 ± 1.33[b]	17.66 ± 0.72[a]	105.29 ± 6.88[a]
ANOVA (P-value)	**0.2741**	**0.3836**	**0.0000**	**0.2854**	**0.0620**	**0.0357**	**0.1453**	**0.8382**	**0.1537**

Notes;Values are expressed as **Mean ± SD**. Means within the same column with different letters differ significantly at **P ≤ 0.05**.

ISSN 2072-3857

Table 10. Egg quality characteristics of eggs produced from laying hens fed diets supplemented with green okra powder and turmeric during Period 5 (27/10–9/11/2025).

Treatment	Egg weight (g)	Shape index (%)	Shell thickness (mm)	Shell weight (%)	Yolk index	Yolk color score	Albumen weight (g)	Yolk weight (g)	Haugh unit
T1 (Control)	64.02 ± 3.92[a]	74.27 ± 2.94[a]	0.44 ± 0.02[a]	9.69 ± 0.73[a]	0.46 ± 0.01[a]	5.00 ± 0.00[a]	37.52 ± 2.90[a]	16.68 ± 0.83[b]	98.20 ± 8.22[a]
T2 (Okra 1 g/kg)	63.48 ± 5.25[a]	74.36 ± 2.48[a]	0.42 ± 0.02[a]	9.42 ± 0.53[a]	0.48 ± 0.03[a]	5.00 ± 0.00[a]	36.50 ± 3.67[a]	17.80 ± 0.48[a]	103.57 ± 5.09[a]
T3 (Okra 2 g/kg)	63.18 ± 4.72[a]	74.52 ± 2.76[a]	0.44 ± 0.01[a]	10.22 ± 0.86[a]	0.43 ± 0.04[b]	4.60 ± 0.89[a]	36.64 ± 2.20[a]	16.50 ± 0.61[b]	96.22 ± 8.22[a]
T4 (Okra 3 g/kg)	65.16 ± 2.98[a]	74.59 ± 3.48[a]	0.41 ± 0.03[a]	9.74 ± 0.36[a]	0.47 ± 0.03[a]	4.80 ± 0.45[a]	38.58 ± 2.76[a]	16.80 ± 0.38[b]	103.14 ± 3.57[a]
T5 (Turmeric 1 g/kg)	65.30 ± 6.25[a]	73.56 ± 1.58[a]	0.39 ± 0.03[b]	8.99 ± 0.91[b]	0.46 ± 0.02[a]	4.60 ± 0.55[a]	37.84 ± 5.80[a]	18.34 ± 0.90[a]	97.90 ± 2.19[a]
T6 (Turmeric 2 g/kg)	65.90 ± 4.31[a]	75.54 ± 2.67[a]	0.41 ± 0.04[a]	9.34 ± 0.55[a]	0.47 ± 0.02[a]	5.00 ± 0.00[a]	39.16 ± 3.71[a]	17.24 ± 0.98[a]	101.87 ± 1.88[a]
T7 (Turmeric 3 g/kg)	62.66 ± 4.08[a]	73.55 ± 1.81[a]	0.43 ± 0.03[a]	9.29 ± 1.15[a]	0.45 ± 0.03[a]	5.00 ± 0.00[a]	37.60 ± 3.90[a]	16.80 ± 1.74[b]	101.58 ± 3.30[a]
ANOVA (P-value)	**0.9024**	**0.9091**	**0.0835**	**0.2786**	**0.1767**	**0.4607**	**0.9137**	**0.0423**	**0.2141**

Notes; Values are expressed as **Mean ± SD**. Means within the same column with different letters differ significantly at **P ≤ 0.05**.

Discussion

Period 1 (1/9–14/9/2025)

In the first stage of production, dietary interventions influenced greatly the egg mass and the feed conversion ratio (FCR), but there was no significant difference in the egg production percentage and egg weight between the groups. The improvement in egg mass of hens fed turmeric at 1g kg^{-1} indicates that low concentration turmeric supplementation could turn out to be beneficial in enhancing nutrient partitioning to egg formation during the initial adaptation phase. Curcumin is also said to increase the release of digestive enzymes and to increase the morphology of the gut, thus increasing its nutrient absorption capability [20]. Better nutrient utilisation is attributable to the superior FCR of the 1kg/g turmeric and 3kg/g okra groups. In addition, curcumin antioxidant potential can potentially suppress oxidative stress in the egg formation process and, as a result, enhance metabolic efficiency [21]. The absence of any substantial changes in the number of eggs produced in this initial period

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of time might be due to the time frame that the birds need to get used to phytogenic supplementation on the physiological level, which is often observed in phytogenic studies [8].

Period 2 (15/9–28/9/2025)

Period 2 showed no significant differences in productive performance; this suggestive of a temporary stabilisation that could be seen as an adaptation of metabolic rates to the level of inclusion of diet. It is a known fact that phytogenic additives are slow acting instead of immediate performance acting [4]. However, there were also notable differences in the shell thickness, percentage shell weight especially in groups supplemented with okra. Okra contains minerals (like calcium and magnesium) and bioactive mucilage compounds, which could increase the efficiency of mineral absorption [22]. Increased mineral use is a direct factor of shell matrix formation and calcification. These results are consistent with the earlier studies which claimed that phytogenic feed additives have the potential of improving mineral metabolism and eggshell quality [9].

Period 3 (29/9–12/10/2025)

Period 3: There was an improvement of the feed conversion ratio in hens fed 2gkg^{-1} okra and turmeric. Most of the performance traits were not statistically significant however, the trend which was observed towards the improvement of FCR indicates increased efficiency of digestion. It has been established that phytogenic compounds can change the composition of gut microbiota favoring beneficial and inhibiting pathogenic population [4]. This microbial modulation can enhance nutrient digestiveness especially at mid-production stages. The percentage of shell weight was also significantly influenced at this time. Such an increase in shell deposition is possibly connected with the positive antioxidant status and underestimation of oxidative stress in the tissues of the shell gland [13].

Period 4 (13/10–26/10/2025) The most responsive period

Period 4 showed the largest treatment responses especially when it comes to egg production, egg mass, FCR and shell thickness. Advanced egg mass and FCR of okra-fed hens at 1g/kg^{-1} indicates that low dose supplementation could be the most economical in terms of optimising metabolic efficiency. Performance on higher levels of inclusion is not always increased, which is probably because there are decreases in palatability or changes in nutrient balance. The tremendous enhancement of egg production in the turmeric 0.5 kg^{-1} group could be associated with the accumulative antioxidant and metabolic efficacies of curcumin. It is also reported that curcumin improves the hepatic lipid metabolic processes and increases vitellogenin synthesis that directly affects the production of yolk precursors [14]. It turned out that shell thickness was very important during this period ($P \leq 0.0001$). The positive effect of improved calcium metabolism and antioxidant shell gland tissue protection could explain the thickened shells in some treatments. The deposition of calcium is impeded by oxidative stress, therefore, phytogenic antioxidants are able to enhance shell formation indirectly [21]. We also saw the advances in yolk colour in the turmeric groups as expected in normal pigmentation deposits. They are absorbed and incorporated into the yolk lipids and increase pigmentation through curcuminoids and carotenoid-like compounds [23], [11].

ISSN 2072-3857

Period 5 (27/10–9/11/2025)

Most of the performance traits returned to non-significant difference in the last period meaning that hens had reached another metabolic balance when under supplementation. The weight of the yolk was considerably elevated in the turmeric 1 gm kg^{-1} group. Improvement in the hepatic lipid metabolism and elevation of the synthesis of very-low-density lipoproteins (VLDL) which is used to carry lipids to the growing follicles is a possibility, which may in turn lead to increased yolk deposition [14]. Even though there have been no significant effects in Haugh unit, numerically higher data of certain of the phytogenic treatments indicate enhanced albumen quality preservation. Proteins of eggs such as albumin can be preserved by antioxidant agents to prevent oxidative destruction and hence retain the quality of the internal eggs [21].

Integrated Interpretation

In general, the findings suggest that the action of okra and turmeric supplementation are dose-dependent, time-dependent, and physiologically adaptive. Okra seems to have more effect on feed efficiency and shell-related characteristics, which can be explained by the fact that it is rich in fibre and minerals, and turmeric seems to have a more pronounced effects on yolk pigmentation and metabolic regulation, which is explained by the presence of curcuminoids. The most predictable biological events that took place in the perceived improvements are improved antioxidant defence, better intestinal performance, improved nutrient use, and regulation of lipid metabolism. Recent phytogenic studies have a solid rationale in support of these mechanisms [20], [8], [4].

Conclusion

Finally, green okra powder and turmeric dietary supplementation showed positive results on the laying performance and egg quality characteristics, especially during the particular production phases. Okra supplementation at 1 g kg sir in relation to feed ratio enhanced the mass of eggs and feed ratio as well as turmeric enhanced the yolk pigmentation and affected the selected traits of quality. The current findings indicate that the two additives can be used as natural phytogenic substitutes of synthetic growth promoters in the nutrition of laying hens. More studies are advisable to examine the long term effects, optimum levels of inclusion and the synergistic action of okra and turmeric under different environmental conditions.

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