Research Journal of Agricultural Sciences
Volume 17; Issue 02 (Mar–Apr 2026); pp 140–145

ISSN: 0976-1675 (P)
ISSN: 2249-4538 (E)

Effects of Dietary Inclusion of Turmeric Rhizome Powder on the External Quality Parameters of Eggs from Fowl-Hens

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Received: 22 Jan 2026; Revised accepted: 25 Feb 2026

Abstract

This study examined the effects of dietary turmeric rhizome powder (TRP) supplementation on the external egg quality traits obtained from laying hens. The experiment was conducted at the Poultry Unit of the Teaching and Research Farm, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria. A total of 192 laying hens (16 weeks old) were randomly allocated to three dietary treatments, each comprising 64 birds. The treatments were further sub-divided into four replicates, with each containing 16 birds. The treatments included a control diet without turmeric (T_1), a diet supplemented with 5 g/kg TRP (T_2), and a diet supplemented with 10 g/kg TRP (T_3). Key parameters assessed included egg weight, shell thickness, shell weight, egg width, egg height, and total egg production. Results indicated a significant difference ($p<0.05$) in total egg production among treatments, with the highest production observed in T_2 (1704 eggs), followed by T_1 (1660 eggs), and the lowest in T_3 (1584 eggs). This suggests that moderate TRP supplementation enhances laying performance, whereas excessive inclusion may induce metabolic constraints. Eggshell thickness was significantly higher ($p<0.05$) in T_3 (0.68 mm) compared to T_2 (0.57 mm) and T_1 (0.53 mm), indicating improved calcium deposition and enhanced shell integrity at higher TRP levels. Eggshell weight also varied significantly ($p<0.05$), with both T_1 and T_3 exhibiting the highest values (5.8 g), while T_2 had the lowest (5.4 g). Egg weight remained statistically unaffected across treatments ($p>0.05$), with mean values of 56.93 g (T_1), 53.70 g (T_2), and 57.70 g (T_3), suggesting that TRP supplementation did not significantly influence overall egg mass. Regarding storage stability, weight depreciation was significantly lower ($p<0.05$) in T_3 (54.10 g to 53.68 g) compared to T_1 (56.96 g to 54.96 g) and T_2 (54.91 g to 52.99 g), reinforcing the role of TRP in maintaining egg mass and reducing moisture loss during storage. The findings suggest that dietary supplementation with 5 g/kg TRP optimizes egg production, whereas 10 g/kg enhances eggshell integrity and storage stability. However, the observed decline in egg production at the higher supplementation level indicates a possible threshold beyond which TRP may negatively impact laying performance. Further research is required to elucidate the physiological mechanisms underlying these effects and to determine the optimal TRP inclusion level for maximizing both egg production and external egg quality traits.

***Key words*:** *Curcuma longa* supplementation, Phytogenic feed additive, External egg quality parameters, Laying hen performance, Egg storage stability

Poultry nutrition experts were particularly interested in investigating natural alternatives to antibiotics that could be used in poultry feed. The goal was to reduce the competitive effectiveness of bacterial resistance and minimize residual traces in poultry products [1]. In recent years, natural medicinal products derived from herbs have been explored as additives in animal feed, including for farm animals [2]. These plant-based products are considered advantageous compared to synthetic antibiotics or inorganic chemicals because they are natural, less toxic and do not leave behind residues. Consequently, they are seen as ideal additives for animal feed in food production [3]. In poultry production, the primary objective is to achieve enhanced performance by improving feed efficiency while ensuring the safety of the final products for consumption [4-5]. Phytogenic feed additives have therefore gained increasing attention in poultry nutrition due to their ability to modulate gut microflora, enhance nutrient utilization, and improve overall bird health without contributing to antimicrobial resistance.

Due to the negative light shed on synthetic feed additives such as antibiotics, researching natural alternatives to improve the production and egg quality of layer hens has become important. Natural feed additives such turmeric and fenugreek have the potential to reduce stress factors and boost production through improved growth and feed intake, as well as improved egg quality.

Turmeric, scientifically known as *Curcuma longa*, is among the various phytogenic additives that hold significance in the production of poultry feed [6]. According to Linnaeus' classification, turmeric belongs to the taxonomic group order Zingiberales, family Zingiberaceae, class *Liliopsida*, subclass *Commelinids*, genus *Curcuma* and species *Curcuma longa*, commonly referred to as turmeric [7]. The medicinal use of

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Citation: Imoru A, Awoneye OO, Oluwasegun OB, Dickson FB, Omosule O. 2026. Effects of dietary inclusion of turmeric rhizome powder on the external quality parameters of eggs from fowl-hens. *Res. Jr. Agril. Sci.* 17(2): 140-145.

turmeric primarily focuses on the rhizome, which is used for human remedies, as well as non-medicinal purposes like food seasoning or feed additives [8]. Turmeric is native to tropical South Asia and thrives in temperatures ranging between 20°C and 30°C [9]. Additionally, turmeric contains a wide range of bioactive compounds most notably curcuminoids and essential oils which are responsible for its antioxidant, anti-inflammatory, antimicrobial, and growth-promoting properties, making it a valuable phytogenic additive in poultry nutrition.

Numerous studies have highlighted the beneficial effects of turmeric on laying hens. For instance, the supplementation of layer diets with 5 g/kg of turmeric meal has been reported to increase the percentage of hen day production (%HDP). Moreover, when hens were fed a diet containing 10 g/kg of turmeric meal, there was a significant improvement in internal and external egg qualities, including egg weight, egg mass, yolk weight and yolk index [10].

However, several other studies have presented contrasting findings regarding the beneficial effects of turmeric that were previously highlighted. Moorthy *et al*. [11] found no significant impact on laying birds and the percentage of hen day egg production when 0.1% turmeric was included in the diet of Single Comb White Leghorn layers. Similarly, Riasi *et al*. [12] reported that feeding laying hens with various levels of turmeric (ranging from 0.0 to 2.0 g/kg of feed) had no significant effect on specific gravity, egg shell thickness, egg shell weight and the ratio of egg shell weight to egg weight. Furthermore, Malekizadeh *et al*. [13] supported these findings by demonstrating that supplementing the diet of single-comb White Leghorn (W-36) laying hens with 10.0 or 30.0 g/kg of turmeric meal did not influence egg production, egg weight or egg mass. The dissimilarities observed in these studies regarding egg traits may be attributed to variations in the environmental conditions, experimental methods employed or possibly due to the dosage of turmeric used, suggesting a potential dose-dependent issue.

MATERIALS AND METHODS

Experimental site

The study was conducted at the poultry unit of the Teaching and Research farm, Rufus Giwa polytechnic, Owo, Ondo state.

Source of experimental materials

Turmeric was purchased from a reputable turmeric farmer at the township market of Emure Ile (Emure market) located at Owo, Ondo State.

Preparation and collection of test ingredient

Fresh turmeric was collected directly from the market and transported to Rufus Giwa Polytechnic Farm. The turmeric was washed, sliced into tiny pieces and air-dried to remove moisture content for three (3) weeks. After drying, the turmeric was milled into powder, referred to as Turmeric Powder.

Experimental birds and their management

Forty-eight (48) layers birds of 16 weeks were purchased from a reliable source. The forty-eight (48) layer birds used for the experiment were assigned to three (3) treatments, four (4) replicates per treatment, with four layers birds in a replicate. Water and feed were supplied as required. Routine management was strictly adhered to. The birds we're fed with experimental diets for 6 weeks.

Experimental diet

The formulated feed used in the experiment contains; maize, wheat offal, soyabean meal, bonemeal, limestone, premix, methionine, salt and lysine.

Three (3) dietary treatments (T_1 - T_3) were formulated using air-dried turmeric milled to powder as an additive.

Treatment 1 (T_1): Control diet with 0g/100kg feed.
Treatment 2 (T_2): Containing 500g/100kg inclusion of turmeric powder.
Treatment 3 (T_3): Containing 1000g/100kg inclusion of turmeric powder.

Table 1 Percentage composition of the experimental layers diet

Ingredients	Diets		
	1	2	3
TRP (g/kg)	0	5	10
Maize	50.00	50.00	50.00
Wheat offal	17.05	17.05	17.05
Soyabean meal	22.00	22.00	22.00
Bone meal	2.00	2.00	2.00
Limestone	8.00	8.00	8.00
Premix	0.25	0.25	0.25
Methionine	0.20	0.20	0.20
Salt	0.30	0.30	0.30
Lysine	0.20	0.20	0.20
Total	100	100	100

Table 2 Calculated analysis

Nutrients	Amounts
Protein (%)	16.64
Energy (Kcal)	2600
Crude Fibre	4.69
Ether Extract	3.80
Calcium	3.74
Phsphorus	0.66
Lysine	1.00

Data collection

The birds were fed with the experimental diet for 6 weeks (42 days) during which data on several parameters were collected and recorded on a weekly basis. Feed intake and weight gain were determined. Egg shell thickness, egg weight and egg shell colour were determined. A scale was used to determine the egg weight, Micro screw gauge were used to determine the eggshell thickness. All the raw data were taken for data analysis.

Statistical analysis

Data collected were subjected to analysis of variance using Duncan multiple range test using ANOVA.

RESULTS AND DISCUSSION

The results of this study demonstrate the effects of dietary turmeric rhizome powder (TRP) supplementation on external egg quality traits of laying hens. The data presented covers both fresh egg quality parameters and egg depreciation characteristics during storage. The external quality parameters of freshly laid eggs are summarized in (Table 3). The measured traits include egg weight, egg height, egg width, eggshell weight, eggshell thickness, and total egg production across the three treatment groups.

Egg weight remained statistically unchanged across treatments ($p > 0.05$). The mean egg weight for the control group (T_1) was 56.93 g, while T_2 and T_3 recorded 53.70 g and

57.70 g, respectively. These results indicate that TRP inclusion at 5 g/kg and 10 g/kg does not significantly influence egg mass.

There was a significant difference in egg height ($p = 0.027$) and width ($p = 0.008$) among treatments. Egg height was highest in T_1 (4.5 cm) and T_3 (4.5 cm), whereas T_2 had a significantly lower height (4.38 cm). Egg width followed a similar trend, with the highest value recorded in T_1 (3.4 cm), a significant reduction in T_2 (3.2 cm), and an intermediate value in T_3 (3.3 cm).

Eggshell weight was significantly influenced by TRP supplementation ($p = 0.00$). The control (T_1) and the highest inclusion level (T_3) recorded the 0.57 mm highest shell weight (5.8 g each), while the lowest shell weight was observed in T_2 (5.4 g).

Shell thickness exhibited a significant increase with increasing TRP levels ($p = 0.001$). The highest shell thickness was recorded in T_3 (0.68 mm), followed by T_2 (0.57 mm), with the lowest value observed in T_1 (0.53 mm).

Total egg production differed significantly across treatments ($p = 0.00$). The highest egg production was recorded in T_2 (426 eggs), while T_1 produced 415 eggs, and the lowest production was observed in T_3 (396 eggs).

Table 3 Effects of dietary phytogenic feed additive (PFA) levels on laying hens performance for fresh egg record external

Level of PFA (g kg $^{-1}$)	Egg weight	Egg height	Egg width	Egg shell weight	Shell thickness	Egg production
T_1	56.93_a	4.5_a	3.4_a	5.8_a	0.53_b	415_b
T_2	53.70_a	4.38_b	3.2_b	5.4_b	0.57_b	426_a
T_3	57.7_a	4.5_a	3.3_{ab}	5.8_a	0.68_a	396_c
p -value	0.00	0.027	0.008	0.00	0.001	0.00

a, b Mean values with different letters in the same column are significantly different ($p < 0.05$)

Egg depreciation and storage stability

The effect of turmeric supplementation on egg preservation and quality characteristics were presented in (Table 4). A significant reduction ($p = 0.000$) in final egg weight was observed among treatments.

The initial egg weight for T_1 was 56.96 g**,** reducing to 54.96 g after storage. T_2 exhibited the highest weight depreciation, with egg weight decreasing from 54.91 g to 52.99 g. Conversely, T_3 had the lowest depreciation, with weight decreasing from 54.10 g to 53.68 g, suggesting greater retention of egg mass during storage.

No significant changes ($p > 0.05$) in egg height and width were observed between initial and final measurements across all treatments. Egg height remained at 4.36 cm in T_1, 4.40 cm in T_2, and 4.39 cm in T_3. Similarly, egg width was unchanged across treatments, indicating that TRP supplementation did not influence the structural dimensions of eggs during storage.

Eggshell thickness did not exhibit significant differences ($p = 0.897$) after storage. While fresh eggs from T_3 had the highest shell thickness, this advantage was not maintained over time.

Shell weight during storage was significantly affected by dietary TRP levels ($p = 0.004$). T_3 recorded the highest shell weight (5.49 g), followed by T_1 (5.29 g), while T_2 had the lowest (5.29 g).

Overall, dietary turmeric rhizome powder, particularly at the T_3 level, demonstrated a beneficial role in maintaining egg mass and shell weight during storage without adversely affecting egg dimensions or shell thickness, indicating its potential to enhance egg storage stability.

Table 4 Effects of dietary phytogenic feed additive (PFA) levels on laying hens performance for Egg storage characteristics

Level of PFA (g kg $^{-1}$)	Initial egg weight	Final egg weight	Initial egg height	Final egg height	Initial egg width	Final egg width	Shell thickness	Shell weight
T_1	56.96_a	54.96_a	4.36_a	4.36_a	3.27_a	3.27_a	0.52_a	5.29_b
T_2	54.91_b	52.99_c	4.40_a	4.40_a	3.23_a	3.23_a	0.52_a	5.29_b
T_3	54.1_b	53.68_b	4.39_a	4.39_a	3.24_a	3.24_a	0.53_a	5.49_a
p -value	0.000	0.000	0.619	0.619	0.308	0.308	0.897	0.004

a, b Mean values with different letters in the same column are significantly different ($p < 0.05$)

Egg cholesterol content

The results of this study assess the effect of dietary turmeric rhizome powder (TRP) supplementation on egg cholesterol content in laying hens. The recorded cholesterol levels were 5.82 mg/g in the control group (T_1), 12.62 mg/g in the 5 g/kg TRP group (T_2), and 23.3 mg/g in the 10 g/kg TRP group (T_3). Despite these numerical differences, the statistical analysis revealed a non-significant effect ($p = 0.434$)**,** indicating that dietary TRP supplementation did not induce a statistically reliable change in egg cholesterol levels among treatments.

The present study investigated the effects of dietary turmeric rhizome powder (TRP) on the external egg quality traits of laying hens. The external characteristics of eggs are key determinants of their marketability, consumer preference, and post-lay preservation [14]. Eggshell integrity, in particular, plays a crucial role in reducing economic losses due to breakage, microbial contamination, and moisture loss during storage [15]. The findings of this study suggest that dietary TRP supplementation has varying effects on egg production, shell characteristics, and overall egg quality, depending on the inclusion level.

Table 5 Effects of dietary phytogenic feed additive (PFA) levels on laying hens performance on egg cholesterol content

Level of PFA (g kg $^{-1}$)	Cholesterol
T_1	5.82
T_2	12.62
T_3	23.3
p -value	0.434

a, b Mean values with different letters in the same column are significantly different ($p < 0.05$)

Egg weight and morphometry

Egg weight is a critical economic trait in poultry production, as it influences both consumer preference and hatchability in breeding programs [16]. The study found no significant differences ($p > 0.05$) in egg weight across the treatment groups, indicating that turmeric supplementation at 5 g/kg and 10 g/kg does not significantly alter egg mass. This aligns with the findings of Abou-Kassem *et al.* [17], who reported that dietary phytogenic feed additives, including turmeric, do not necessarily influence egg weight unless they significantly enhance nutrient bioavailability or protein metabolism.

However, a reduction in egg width and height was observed in the 5 g/kg TRP group (T_2) compared to the control, while the 10 g/kg TRP group (T_3) exhibited intermediate values. Variations in egg dimensions may be influenced by calcium metabolism, shell gland activity, and hormonal regulation of oviposition [18]. Egg shape index, a function of egg width and height, is an important trait linked to shell strength and breakage resistance [19]. The reduction in egg width at 5 g/kg TRP suggests a potential impact on egg formation processes, possibly mediated through alterations in mineral metabolism.

Eggshell characteristics

Eggshell quality particularly thickness and weight is a major determinant of egg durability, especially in commercial egg production where breakage rates directly affect economic efficiency [14]. The study, conducted at the poultry unit of the Teaching and Research Farm, Rufus Giwa Polytechnic, Owo, Ondo State, revealed a significant improvement ($p < 0.05$) in eggshell thickness with increasing dietary TRP levels. The highest eggshell thickness values were recorded in birds fed 10 g/kg TRP. This finding suggests that turmeric may enhance calcium deposition and eggshell formation, potentially through its bioactive compounds such as curcumin, which have been reported to improve mineral absorption and retention [20]. Several studies have highlighted the role of curcumin in enhancing bone and eggshell mineralization. Gheisar *et al.* [21] reported that phytogenic feed additives, including turmeric, promote intestinal calcium absorption by modulating gut microbiota and enhancing digestive enzyme activity. Furthermore, turmeric has been shown to exert antioxidant effects that mitigate oxidative stress in laying hens, thereby optimizing calcium metabolism and reducing eggshell defects [22]. The increased eggshell weight in T_3 further supports the hypothesis that turmeric improves eggshell integrity, which is essential for reducing production losses due to fragile shells.

It is important to note that while the highest TRP inclusion level (10 g/kg) improved shell thickness, it did not enhance egg production, suggesting that excessive supplementation may exert metabolic constraints that offset its beneficial effects on eggshell quality.

Egg production performance

Egg production is influenced by a range of factors, including nutrient availability, metabolic health, and reproductive physiology [23]. The highest egg production was recorded in the 5 g/kg TRP group (T_2), which was significantly higher than both the control (T_1) and the 10 g/kg TRP group (T_3). This suggests that moderate levels of turmeric supplementation may enhance laying performance, potentially through improvements in nutrient digestion and absorption.

Curcumin, the principal bioactive compound in turmeric, has been reported to have anti-inflammatory, antimicrobial, and digestive-enhancing properties [24]. These effects may lead to improved gut health, increased nutrient utilization, and consequently, enhanced reproductive performance in laying hens. Similar findings have been reported by Al-Shuwaili *et al.* [25], who demonstrated that dietary turmeric improved feed efficiency and laying performance due to its positive effects on gut microbiota and intestinal health.

However, a significant decline in egg production was observed at the highest inclusion level (10 g/kg TRP). This may be attributed to possible metabolic stress or reduced feed palatability, which could limit nutrient intake. Excessive phytogenic additives have been associated with negative impacts on reproductive performance, likely due to alterations in endocrine function or energy partitioning [26]. The observed decrease in egg production at 10 g/kg TRP suggests that there is a threshold beyond which turmeric supplementation may no longer be beneficial and may instead exert inhibitory effects on ovarian function or egg formation.

Egg depreciation and storage quality

Egg storage stability is a key concern in commercial egg production, as moisture loss and shell deterioration reduce egg quality over time [27]. The study found that final egg weight depreciation was significantly higher in T_2 (5 g/kg TRP) compared to T_3 (10 g/kg TRP), suggesting that turmeric at higher levels may help preserve egg mass during storage. This aligns with previous studies indicating that eggshell thickness is directly correlated with reduced moisture loss during storage [15].

Shell weight was also significantly higher in the 10 g/kg TRP group, further reinforcing the role of turmeric in improving eggshell integrity. The ability of turmeric to enhance eggshell strength may contribute to extended shelf life and reduced spoilage, which is beneficial in both small-scale and industrial egg production systems. Gheisar *et al.* [21] suggested that the antioxidant properties of turmeric may reduce lipid peroxidation in the eggshell matrix, thereby maintaining shell structure over time.

Egg cholesterol

The current study evaluated the impact of dietary turmeric rhizome powder (TRP) supplementation on egg cholesterol content in laying hens. The results indicate a numerical increase in cholesterol levels with increasing TRP inclusion; however, the differences among treatments were not statistically significant ($p = 0.434$). These findings suggest that turmeric supplementation, at the levels tested, did not exert a consistent or significant effect on cholesterol metabolism in laying hens.

Egg cholesterol content is a critical factor in poultry nutrition and human health, as eggs are a primary dietary source of cholesterol [18]. Previous studies have reported conflicting results regarding the effect of turmeric on lipid metabolism in poultry. Some researchers have demonstrated that turmeric and its active compound, curcumin, possess hypocholesterolemic properties through their ability to regulate lipid absorption, reduce hepatic cholesterol synthesis, and enhance bile acid excretion [23]. Conversely, other studies have shown either neutral effects or cholesterol elevations, depending on dosage, bioavailability, and dietary composition [22].

In the present study, the observed increase in cholesterol content with TRP supplementation may be attributed to multiple physiological mechanisms. One possible explanation is enhanced lipid absorption**,** as turmeric has been reported to improve intestinal health and nutrient assimilation [21]. The increased bioavailability of dietary lipids could have contributed to higher cholesterol deposition in the eggs. Additionally, cholesterol serves as a precursor for steroid hormone synthesis, and phytogenic feed additives, including turmeric, have been shown to influence endocrine function in poultry [20]. It is possible that TRP supplementation modulated steroidogenesis, leading to a compensatory increase in cholesterol levels.

Another potential factor influencing these findings is the dose-dependent metabolic response to curcumin. While curcumin has been widely recognized for its antioxidant and anti-inflammatory properties, its lipid-modulating effects are complex and may vary depending on the physiological state of the birds and overall dietary composition [25]. High-dose TRP inclusion (10 g/kg) could have triggered metabolic adjustments that resulted in increased cholesterol synthesis rather than the expected reduction. The absence of statistical significance suggests that these effects may not be strong enough to produce consistent and reproducible changes in cholesterol levels under the tested conditions.

The findings also underscore the importance of dietary interactions in determining the efficacy of turmeric as a lipid-modulating agent. The background diet composition, particularly the ratio of saturated to unsaturated fatty acids, influences how turmeric affects cholesterol metabolism [24]. Additionally, curcumin's low bioavailability in poultry may have limited its ability to exert significant hypocholesterolemic effects at the tested inclusion levels. The inclusion of bioavailability enhancers, such as piperine from black pepper, has been shown to improve curcumin absorption and enhance its physiological effects [20] and future studies may explore such combinations for potential cholesterol-lowering benefits.

From a practical standpoint, the results suggest that TRP supplementation at 5 g/kg and 10 g/kg does not significantly alter egg cholesterol content, making it unsuitable as a stand-alone strategy for cholesterol reduction in eggs. However, the numerical trend toward increased cholesterol levels at higher TRP doses warrants further investigation. Future research should consider the long-term effects of turmeric on lipid metabolism, as well as its interactions with other dietary factors that influence cholesterol deposition in eggs. Additionally, molecular studies assessing gene expression related to lipid metabolism could provide deeper insights into the underlying mechanisms of TRP's effects on cholesterol regulation in laying hens.

CONCLUSION

The current study investigated the effects of dietary turmeric rhizome powder (TRP) supplementation on the external egg quality traits of laying hens. The findings revealed that TRP inclusion at 10 g/kg significantly enhanced eggshell thickness and weight, indicating improved calcium deposition and shell integrity. Additionally, eggs from the 10 g/kg TRP group exhibited lower weight lost during storage, suggesting superior preservation characteristics. However, egg production was highest in hens supplemented with 5 g/kg TRP, whereas a decline was observed at the 10 g/kg inclusion level, indicating a potential metabolic threshold beyond which TRP may exert inhibitory effects on reproductive performance. Egg weight and morphometric parameters were not significantly affected by TRP supplementation. Furthermore, dietary TRP did not induce a statistically ($P<0.05$) significant effect on egg cholesterol levels, although a numerical increase was observed at higher inclusion levels. These results suggest that TRP supplementation positively influences certain external egg quality traits, particularly eggshell strength and storage stability, but its effect on egg production performance is dose-dependent. While moderate supplementation (5 g/kg) enhances laying performance, excessive inclusion (10 g/kg) may compromise productivity, necessitating careful dietary formulation.

LITERATURE CITED

1. Gholami-Ahangaran M, Karimi-Dehkordi M, Akbari Javar A, Haj Salehi M, Ostadpoor M. 2021. A systematic review on the effect of ginger (*Zingiber officinale*) on improvement of biological and fertility indices of sperm in laboratory animals, poultry and humans. *Veterinary Medicine and Science* 7(5): 1959-1969.
2. Guo FC. 2003. Mushroom and herb polysaccharides as alternative for antimicrobial growth promoters in poultry. *Ph. D. Dissertation*. Wageningen University.
3. Wang R, Li D, Bourne S. 1998. Can 2000 years of herbal medicine history help us solve problems in the year 2000. *Alltechs Annual Symposium* 14: 168-184.
4. Bahmani M, Abdi F, Adineh A. 2014. The anti-leech effect of ethanolic extract of *Achillea millefolium* L. compared to Levamisole and Niclosamide on *Limnatis nilotica*. *Studia Universitatis Vasile Goldis Seria Stiintele Vietii (Life Sciences Series)* 24(3): 100-110.
5. Gholami-Ahangaran M, Peimani N, Ahmadi-Dastgerdi A. 2019. The effect of thyme *(Thymus daenensis*) supplement on growth and hygienic parameters of broilers meat. *Iraqi Journal of Veterinary Science* 33(1): 87-92.
6. Olarotimi OJ. 2018. Turmeric (*Curcuma longa*): An underutilized phytogenic additive in poultry nutrition. *Turkish Journal of Agriculture-Food Science and Technology* 6(1): 102-106. 10.24925/turjaf.v6i1.102-106.1572
7. Khulel R. 2023. A use of turmeric (*Curcuma longa*) in poultry nutrition: A review: Turmeric in poultry nutrition. *Journal of Agricultural and Marine Sciences* 28(2): 1-6.
8. Dono ND. 2014. Turmeric (*Curcuma longa* Linn.) supplementation as an alternative to antibiotics in poultry diets. WARTAZOA. *Indonesian Bulletin of Animal and Veterinary Sciences* 23(1): 41-49.
9. Khan RU, Naz S, Javdani M. 2012. The use of turmeric (*Curcuma longa*) in poultry feed. *World's Poultry Science Journal* 68(1): 97-103.
10. Radwan Nadia L, Hassan RA, Qota EM, Fayek HM. 2008. Effect of natural antioxidant on oxidative stability of eggs and productive and reproductive performance of laying hens. *International Journal of Poultry Science* 7(2): 134-150.
11. Moorthy M, Saravanan S, Mehala C. 2009. Performance of single comb white leghorn layers fed with aloe vera, *Curcuma longa* (turmeric) and probiotic. *International Journal of Poultry Science* 8: 775-778.
12. Riasi A, Kermanshahi H, Fathi MH. 2008. Effect of turmeric rhizome powder (*Curcuma longa*) on performance, egg quality and some blood serum parameters of laying hens. *In*: Proceeding 1st Mediterranean Summit of World Poultry Science Association, Greece. Beekbergen, Netherlands: World Poultry Science Association.
13. Malekizadeh M, Moeini MM, Ghazi S. 2012. The effects of different levels of ginger (*Zingiber officinale* Rosc) and turmeric (*Curcuma longa* Linn) rhizomes powder on some blood metabolites and production performance characteristics of laying hens. *Journal of Agricultural Science Technology* 14: 127-134.

14. Roberts JR. 2019. Factors affecting egg internal quality and eggshell quality in laying hens. *The Journal of Poultry Science* 56(1): 1-9. https://doi.org/10.2141/jpsa.0180028
15. Aygun A. 2021. The relationship between eggshell thickness and egg quality traits in Japanese quail eggs. *Poultry Science Journal* 9(1): 23-30. https://doi.org/10.22069/PSJ.2021.18275.1726
16. Narinc D, Aygun A, Karaman E, Aksoy T. 2014. Egg quality traits in Japanese quail: Genetic parameters and the effects of selection for live weight. *British Poultry Science* 55(5): 615-623. https://doi.org/10.1080/00071668.2014.958051
17. Abou-Kassem DE, Mahrose KM, El-Sawy HB. 2021. Impact of dietary phytogenic feed additives on laying performance, egg quality, and blood metabolites of hens under heat stress conditions. *Animal Feed Science and Technology* 275: 114890. https://doi.org/10.1016/j.anifeedsci.2021.114890
18. Morsy AS, Shafey TM, Abou-Kassem DE. 2022. Effects of dietary calcium sources and levels on productive performance, egg quality, and bone parameters of laying hens. *Poultry Science* 101(1): 101518. https://doi.org/10.1016/j.psj.2021.101518
19. Tumova E, Gous RM. 2012. Interaction of hen production type, age, and temperature on laying pattern and egg quality. *Poultry Science* 91(5): 1269-1275. https://doi.org/10.3382/ps.2011-01853
20. Hassan FAM, Mohamed MA, Youssef AW. 2020. Effect of dietary supplementation with turmeric (*Curcuma longa*) powder on performance, egg quality, and some blood parameters in laying hens. *Journal of Animal and Feed Sciences* 29(1): 51-60. https://doi.org/10.22358/jafs/115524/2020
21. Gheisar MM, Kim IH, Pham VH. 2020. Effects of phytogenic feed additives on growth performance, nutrient digestibility, and meat quality in poultry: A review. *Poultry Science* 99(3): 1328-1339. https://doi.org/10.1016/j.psj.2019.10.063
22. Rehman ZU, Meng C, Sun Y, Rehman H. 2019. Antioxidant potential of polysaccharides and their derivatives for the prevention and treatment of liver diseases: A comprehensive review. *International Journal of Biological Macromolecules* 123: 229-240. https://doi.org/10.1016/j.ijbiomac.2018.11.041
23. Alagawany M, Farag MR, Dhama K, Abd El-Hack ME. 2021. Nutritional significance and health benefits of designer eggs. *World's Poultry Science Journal* 77(1): 1-14. https://doi.org/10.1017/S004393392000060X
24. Islam KMS, Schuhmacher A, Gropp JM. 2023. Humic acid substances in animal agriculture. *Pakistan Journal of Nutrition* 22(1): 1-12. https://doi.org/10.3923/pjn.2023.1.12
25. Al-Shuwaili MA, Al-Daraji HJ, Al-Mashadani HA. 2022. Effect of dietary turmeric powder supplementation on productive performance and egg quality traits of laying hens. *Iraqi Journal of Veterinary Sciences* 36(1): 45-52. https://doi.org/10.33899/ijvs.2022.132266.1978
26. Mansoub NH. 2011. Comparative effects of using turmeric, garlic, and thyme on performance and gut microflora in broilers. *Global Veterinaria* 7(2): 149-153.
27. Samli HE, Agma A, Senkoylu N. 2005. Effects of storage time and temperature on egg quality in old laying hens. *Journal of Applied Poultry Research* 14(3): 548-553. https://doi.org/10. 1093/japr/14.3.548.