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INFLUENCE OF DIETARY TURMERIC AND CURCUMIN SUPPLEMENTATION ON THE PRODUCTIVE AND REPRODUCTIVE PERFORMANCE OF GIMMIZAH LAYING HENS

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ABSTRACT: This study aimed to evaluate the impact of the nutraceuticals turmeric (Tur) or curcumin (Cur) affected the biochemical parameters, productivity, and quality of eggs in layers. In these study 168 hens, from 32 to 44 weeks, were housed individually in single cages and distributed randomly into seven distinct groups consisting of three replicates, with eight birds in each group. The first group received the basal diet and served as the control group. The second, third, and fourth groups were fed diets supplemented with 1, 2, and 3gm of Tur/kg diet, respectively, while the fifth, sixth, and seventh groups were provided diets augmented with 50,100, and 150 mg of Cur/kg diet, respectively. The study's findings indicate a notable rise in egg production by (21.09%) and (14.62%) when fed diets supplemented with 3g/kg Tur and 150 mg Cur /kg, respectively, compared to the control group. The inclusion of turmeric and curcumin in the diet also led to a significant improvement in the feed conversion ratio. Additionally, both supplements positively impacted the yolk color score, with statistical significance ($P \leq 0.05$). Results showed that treated groups with Tur and Cur exhibited a significant ($P \leq 0.05$) increase in total protein, albumin, and globulin, calcium, and phosphorus levels compared to the control group. Furthermore, supplementation with Tur or Cur exhibited a statistically significant ($P \leq 0.05$) enhancement in lipid profile, antioxidant status, immunity, and hormone levels compared to the control group. These results suggest that incorporating Tur (3g/kg) or Cur (150 mg/kg) as dietary nutraceuticals in laying hen feed could effectively enhance productive performance, egg quality, and biochemical parameters.

Keywords: Turmeric -Curcumin - Laying hens - Biochemical parameters - Economic efficiency.

INTRODUCTION

In light of current trends aimed at improving food and feed security, reducing environmental pollution, as well as mitigating health risks, it is essential to identify strategies for minimizing synthetic ingredients in our food and enhancing the use of environmentally friendly products (El-Sahn *et al*., 2024). Throughout history, ancient civilizations have utilized medicinal herbs (nutraceuticals), which are gaining popularity as natural substitutes for synthetic pharmaceuticals in all communities (El-Sabrout *et al*., 2023). The use of medicinal plants has increasingly attracted attention a significant focus, particularly in the realm of livestock nutrition (El-Speiy *et al*., 2022; Khalifah *et al*., 2021a).

Turmeric (*Curcuma longa*), a bright yellow spice derived from the rhizomes of the Curcuma plant, has been used in culinary and healthcare applications for thousands of years, particularly in South Asian traditions. The use of turmeric (Tur) in natural health care is due to its capability to enhance the immune system, increase (stimulate) appetite, and possess (exhibit) antioxidant and antibacterial qualities (properties) (Liu *et al*., 2020). A detailed examination of the powdered Tur revealed that it contains between 2.4% and 4% of essential oils (Kermanshahi and Riasi, 2006).Dalal and Kosti (2018) demonstrated that the biologically active constituents of oil produced from turmeric include curcuminoids (32.5%), α turmerones (15.6%), and ß turmerones (17.1%).

Numerous studies have demonstrated that Tur, when used as a dietary supplement, can exert significant effects on poultry performance and health. Emadi and Kermanshahi (2007) reported that laying hens fed diets supplemented with turmeric powder exhibited improved liver function compared to untreated controls Furthermore; turmeric supplementation has been associated with enhanced gastrointestinal enzyme activity, improved hepatic integrity, and decreased serum cholesterol concentrations in livestock (Platel and Srinivasan, 2000; Van Phuoc *et al*., 2019). Additionally, chickens ingested Tur with a dosage of 5 g/kg exhibited improved energy utilization and conversion ratios for feed (Attia *et al*., 2017). Moreover, Salah *et al*. (2021) found that dietary turmeric improved antioxidant status and performance in broilers exposed to environmental stress.

In addition, the inclusion of 5% turmeric flour in the diets of quail was associated with enhanced egg production, improved egg quality, and increased economic return (Zacaria and Ampode, 2021).

Curcumin (1, 7-bis (4-hydroxy-3-methoxyphenyl) hepta-1, 6-diene-3, 5-dione; diferuloylmethane), a major bioactive polyphenol extracted from turmeric (*Curcuma longa*) rhizomes, is responsible for turmeric's characteristic yellow hue and other medicinal properties (Kumar *et al.,* 2019). The level of Cur in powdered turmeric is approximately 7.9% (Saraswati *et al.,* 2013). Curcumin (Cur) exhibits a wide range of biological activities, including antioxidant, antibacterial, and anticancer effects (Sharma *et al*., 2005; Liu *et al*., 2020). It is recognized for its ability to scavenge reactive oxygen species, inhibit lipid peroxidation, and protect cellular macromolecules, including DNA, from damage caused by oxidative stress (Srinivasan *et al*., 2006). Additionally, Curcumin exerts potent anti-inflammatory effects by generates an anti-inflammatory impact through the inhibition of various critical molecular mechanisms associated with inflammation (Aggarwal *et al*., 2007). The cancer prevention properties of Cur have received considerable interest. Preclinical investigations indicate that Cur inhibits cancer cell proliferation, induces apoptosis, and reduces the expansion of tumors. This intervention targets different molecular mechanisms associated with the progression of cancer, specifically those linked to cellular cycle regulation and apoptosis (Bimonte *et al*., 2016; Kunnumakkara *et al*., 2017).

The application of Cur in farm animals demonstrates potential physiological and immunological benefits. Curcumin reduces oxygen depletion by modulating Nrf2/HO-1 mechanism in quails exposed to thermal stress (Sahin *et al*., 2012a). it enhances the production of antioxidant enzymes and improves immune response in layer chicks (Liu *et al*., 2020). Furthermore, the use of natural Cur nano-particles modulates has also been reported to regulate antioxidant enzyme activity, modulate immune responses, and influence gut macrobiotic composition in quails (Reda *et al*., 2020). Investigations into Cur within the context of livestock farming remain in the early stages of development. Curcumin alleviated thermal stress by influencing liver nuclear transcription variables and heat shock protein 70 in quails exposed to thermal stress (Sahin *et al*., 2012b). Notably, curcumin alleviated heat-induced stress by regulating hepatic nuclear transcription factors and the expression of heat shock protein 70 in thermally stressed quails (Sahin *et al*., 2012b).

This research aims to compare the use of Tur powder as a raw material and its active component curcumin, at different dietary inclusion levels on productivity, egg quality, and biochemical profile of laying hens. The objective is to determine the most effective form of supplementation, either whole turmeric or isolated curcumin, for improving performance in layers.

MATERIALS AND METHODS

This study was carried out at El-Sabahia Poultry Research Station (Alexandria), Animal Production Research Institute (APRI), Agricultural Research Center, Egypt.

Birds, Management, and Experimental Design

A total of one hundred and sixty-eight laying hens of Gimmizah strain at 32 weeks of age were weighed and randomly distributed into seven experimental groups, 24 hens each, with three replicates (8 hens) and housed in individual cages. All birds were housed under similar hygienic and managerial conditions. Throughout the experimental period (32 -44 weeks of age), the first group was fed the basal diet without supplementation (control). The second, third, and fourth groups were fed the basal diet supplemented with turmeric (Tur) at 1, 2, and 3 g/kg diet, respectively. The fifth, sixth, and seventh groups were fed a basal diet supplemented with curcumin (Cur) at 50, 100, and 150 mg/kg, respectively. The basal diet covered the nutrient requirements according to the feed composition in Table for Animal and Poultry Feedstuffs in Egypt, as shown in Table 1. Vaccination and medical care were done according to common veterinary care under the veterinarian’s supervision.

Productive Performance Measurements

Egg production (EP) and egg weight (EW) were recorded daily for each replicate. Egg mass (EM) was calculated by multiplying the number of eggs by average egg weight. Feed intake (FI) was recorded every week. Egg production was expressed as a percentage during the experimental period (32–44 weeks of age).The feed conversion ratio (FCR) was calculated as g of feed consumed per g of egg mass produced (g feed/g EM).

External and Internal Egg Quality

At 36, 40, and 44 weeks of age, fifteen eggs per group were randomly selected to evaluate egg quality traits. The weight of the yolk, albumen, and eggshell was measured and expressed as a percentage of total egg weight. Eggshell thickness (excluding shell membranes) was measured in millimeters (mm).

Eggshells were washed and air-dried at room temperature for 72 hours, then individually weighed, and their relative shell weights were calculated as a percentage of the whole egg weight. Shell thickness was determined at three equatorial regions on ten eggs per group using a manual micrometer.

Then, records of yolk index (YI) were measured according to Funk (1948).Yolk color was assessed visually using the 15-point Roche Improved Yolk Color Fan (1961 edition) by matching each yolk with the closest color band.

Biochemical and Hormonal Assays

At the end of the experimental period (9:00 AM), two blood samples (3 mL each) were withdrawn from the brachial vein of three hens per replicate. One sample was collected in tubes containing anticoagulant (for plasma separation), and the other in plain tubes (for serum separation). All plasma and serum samples were stored at −20°C until analysis.

Plsma total protein and albumine, serum aspartate aminotransferase (AST) and alanine aminotransferase (ALT) activities were determined spectrophotometrically using commercial kits. Plasma total lipids, cholesterol, high-density lipoprotein (HDL), and low-density lipoprotein (LDL) were determined using Diamond Diagnostics Company (29 Tahreer St. Dokki Giza Egypt). Serum total antioxidant capacity (TAC) and malondialdehyde (MDA) levels were assessed calorimetrically using commercial assay Kits. Serum immunoglobulins (IgG and IgM) were measured using a commercial ELISA kit, following the procedure of Bianchi *et al*. (1995).

Plasma Estrogen (E_2) and Progesterone (P_4) were determined using radioimmunoassay (RIA) kits (Diagnostic Systems Laboratories, USA) with an Automatic 1275 MiniGamma Counter (LKB), following the protocol of Canez*et al.* (1992). The estrogen-to-progesterone ratio (E_2/P_4) was subsequently calculated.

Economic Efficiency

The economic efficiency of egg production was evaluated using input-output analysis based on the cost of the experimental diets and the value of egg production during the year 2022. Economic efficiency was expressed as the net revenue per unit of total cost.

Statistical Analysis

Data were statistically analyzed using one-way ANOVA of SAS® (SAS Institute, 2004). Differences among treatment means were estimated by Duncan's multiple range test (Duncan, 1955). The following model was used to study the effect of treatments on the parameters investigated as follows: $Y_{ij} = \mu + T_i + e_{ij}$. Where: Y_{ij} = an observation, μ = overall mean, T_i = effect of i^{th}treatments (i=1, 2, 3, 4, 5, 6, and 7), and e_{ij} = experimental random error.

RESULTS AND DISCUSSION

Productive Performance

As shown in Table 2, the egg production percentage (EP%) for layer groups fed diets supplemented with turmeric (Tur) or curcumin (Cur) was significantly increased throughout the experimental period compared to the unsupplemented control group. Notably, hens fed on a diet containing 3 g Tur/kg diet significantly increased EP by 21.1% than those fed the basal diet. Similarly, groups receiving 2g Tur/kg diet, 150 mg Cur/kg or 100 mg Cur /kg diet exhibited significant increases in egg production by 15.2, 14.6 or 12.1% respectively, relative to the control. However, supplementation with 1 g Tur/kg or 50 mg Cur/kg did not significantly affect EP when compared to the control group. Moreover, hens fed diets containing 3, 2 or 1 g Tur/kg diet and those fed on 150 or 100 mg Cur/kg diet, exhibited a significant increase in egg mass compared to the control. No significant differences were observed in egg mass in the group supplemented with 50 mg Cur/kg relative to the control.

Furthermore, the data showed a significant improvement in the feed conversion ratio (FCR) in hens fed diets supplemented with either Tur or Cur diet compared to the control diet. However, the results showed that there was no significant effect as a result of adding either Tur or Cur to dietary hens on egg weight (EW) and feed consumption (FC).

Overall, the group of laying hens fed a diet supplemented with 3g Tur/kg demonstrated the most favorable results in terms of egg production (EP), egg mass (EM), and FCR compared to the control group.

These findings are consistent with those of Park *et al*. (2012), who indicated that dietary inclusion of turmeric flour at levels of 1, 2.5, or 5 g/kg significantly raised egg production ($p < 0.05$) in Lohman Brown layers in comparison to unsupplemented control. Additionally, Kanagaraju *et al.* (2017) stated that supplementation with Tur powder at 0.5% significantly ($p < 0.05$) enhanced egg production. In contrast, the results differ from those of Widjastuti and Setiawan (2017) demonstrated that egg weight (EW) and egg production (EP) were considerably enhanced ($P< 0.05$) in layers that received a feed augmented by 1g/kg and 2g/kg Tur compared to control birds.

Mirbod *et al.* (2017) reported that dietary supplementation with turmeric powder at 2.0 and 6.0 g/kg significantly improved egg mass (EM) and feed conversion ratio (FCR) compared to the control group. Likewise, Samia *et al.* (2018) discovered that EM was considerably ($p<0.05$) enhanced and a reduction in FCR when hens were fed diets augmented with 6 g/kg of Tur flour, in comparison to 4 g/kg of Tur and untreated administrations. As a result of improving the efficiency of absorbing nutrients into eggs, Fawaz *et al.* (2023) discovered that EM and FCR enhanced with inclusion of Tur powder at doses of 2.5, 5, and 7.5 g/kg. These enhancements were attributed to more efficient nutrient assimilation into the egg, possibly due to turmeric's influence on intestinal enzyme activity and bile secretion (Gandhi *et al.*, 2011; Van Phuoc *et al.*, 2019). Enhanced laying performance may thus be primarily driven by improved digestive efficiency and nutrient bioavailability.

Curcumin is recognized for its ability to modulate various signaling pathways either directly or indirectly (Liu *et al.*, 2020). This bioactive polyphenol exhibits pleiotropic properties and has shown therapeutic potential in various animal models of human diseases (Gupta *et al.*, 2012). Based on our hypothesis, the positive physiological effects observed in poultry may be attributed to Cur's regulatory influence on signaling mechanisms involved in metabolic and immune function.

Regarding to Cur effect, Liu *et al.* (2020) observed that when inclusion of 150 mg/kg of Cur was included instead of the control dose, they increased significantly egg production (EP) and improved feed conversion ratio (FCR). In contrast, Liu *et al.* (2024) observed that supplementation with 200 mg/kg in quail diets had no significant effect on egg mass (EM) or FCR, suggesting that the response to Cur may be species - or dose-dependent.

Egg Quality

Dietary supplementation of laying hen diets with turmeric (Tur) and curcumin (Cur) at different inclusion levels significantly improved yolk color score compared to the control diet. However, other egg quality parameters, including albumen weight, yolk weight, egg shape index, yolk index, shell weight, and shell thickness were not significantly affected by the inclusion of either additives at different levels compared with the control group (Table 3).

These observations contrast with the findings of Fawaz *et al.* (2023), who showed that turmeric (Tur) supplementation enhanced the uterine environmental source of calcium resulting in enhanced eggshell quality, including increased shell weight and thickness, in treated birds compared to the controls. Concurring with our results, Radwan *et al.* (2008) observed eggshell mass and thickness enhancement with dietary inclusion of turmeric at 5g/kg and 10g/kg compared to unsupplemented group. Samia *et al.* (2018) noted that the addition of 6 g/kg of Tur powder to the diets of Golden Montazah layers dramatically enhanced shell weight, while albumen weight remained comparable to the untreated set. Our results, however, diverge from those presented by Riasi *et al.* (2012), which determined that the thickness and weight of eggshells remained unaffected by the inclusion of Tur powder at levels of 0.5, 1, 1.5, and 2 g/kg. A dosage of 1, 2.5, or 5g/kg Tur powder did not influence shell thickness according to Park *et al.* (2012). Also, Widjastuti and Setiawan (2017) found no effect on shell thickness or yolk index, when Tur was added to the dietary intake of layers at 1g/kg and 3g/kg.

According to Gums *et al.* (2018), shape, albumen, and yolk index were unaffected by supplementing laying hens' diets with 0.5% Tur compared to the untreated set. Saraswati and Tana (2016) discovered that dietary inclusion of Tur flour at 54 mg and 108 mg per day in quails resulted insimilar shell weight and eggshell thickness to the untreated set. Increased feed intake in layers treated with Cur leads to higher blood calcium levels. This enhances the production and quality of eggshells, as supported by Liu et al. (2020).Liu *et al*. (2024) discovered that administering 200 mg/kg of Cur to quails makes their egg shells thicker and stronger compared to the untreated set.

Biochemical Constituents

Protein profile

Results in Table 4 showed that the study revealed dietary supplementation with either Tur or curcumin (Cur) significantly increased total protein, albumin, and globulin concentrations compared to the control group. Turmeric at 2-3g/kg increased total protein by 11.2%, and curcumin also exhibited increased effects (5.5% increases at 150mg/kg). Curcumin (50mg/kg) boosted albumin by 2.5% (3.32 vs 3.24 g/dl), while turmeric (2g/kg) elevated globulins by 35.6% (3.01 vs 2.22 g/dl).This reflects an increase in globulin levels, which is associated with enhanced immune function. Studies have shown that groups fed both additives at different levels, Tur and Cur, can enhance blood protein and calcium concentrations, both of those being critical for optimal egg production. (Samia *et al*., 2018; Fawaz *et al*., 2023). Our results align with those documented by Ramadan and Madeha (2020) demonstrated that supplementing diets with 0.5 and 0.75% turmeric powder (Tur) in Fayoumi broilers a significant increased in total protein and globulin. Abdelkader *et al*., (2023) found that Total protein significantly increased in the groups of curcumin at 75,100 mg/kg diet compared with the control group. The results showed that plasma globulin significantly increased in all levels of curcumin (50, 75,100 mg/kg diet) compared with the control group. There were no significant differences in plasma albumin and albumin/globulin ratio among different groups. Mengjie *et al*., (2020) found that the addition of curcumin to the diet of laying hens had little influence on the physiology of birds. No changes in serum total protein, ALB, or GLU concentrations were observed during the whole experiment period in either of the experimental treatment groups compared with the control group. Discrepancies observed in different research may be attributed to variations in plant chemical structure, supplementation levels, application methods, bird species, housing conditions, and bioactive components (Attia *et al*., 2018; Khalifah *et al*., 2021b).

Indices of Liver Enzymes

Table 4 presents the biochemical composition of serum liver enzymes and their respective functions. The results demonstrate a progressive decrease in AST levels with increasing turmeric doses, culminating in a 25.8% reduction at 3 g/kg (36.19 vs. 48.74 U/L in the control group). Similarly, ALT levels exhibited a marked decrease, showing a 37.1% reduction at 2 and 3 g/kg turmeric doses (12.27 and 12.42 vs. 19.74 U/L in the control). These findings suggest a potential enhancement in liver function, likely linked to the immunostimulatory, antifatigue, and hepatoprotective properties of turmeric and curcumin, as highlighted in earlier studies by Wu and Zhong (1999) and Azazi *et al*. (2011).

Serum AST and ALT levels are widely regarded as reliable markers for assessing liver function and detecting potential hepatic damage.

Serum AST and ALT levels are widely regarded as reliable markers for assessing liver function and detecting potential hepatic damage. According to Fawaz *et al*. (2023) demonstrated that supplementing diets with turmeric (Tur) in laying hens between the ages of 55 and 67 weeks may not have caused any toxicity, which is supported by the results of the current investigation. The findings are physiologically normal (Emadi and Kermanshahi, 2007;Akbari *et al*., 2016)

Blood Glucose Concentration

Data presented in Table 4 demonstrated that supplementation with turmeric (Tur) or curcumin (Cur) significantly improved glucose metabolism, reflected by lower blood glucose levels. Hens consuming diets with 2 or 3 g Tur/kg exhibited a 21.4% decrease in blood glucose concentrations (127.9–128.6 mg/dL compared to 162.7 mg/dL in the control group). Similarly, supplementation with 100 or 150 mg Cur/kg led to reductions in blood glucose levels by 8.8% and 19.7%, respectively (148.4–130.6 vs. 162.7 mg/dL). Birds receiving 1 g Tur/kg or 50 mg Cur/kg displayed moderate responses between these values. Glucose, being the primary monosaccharide driving energy metabolism in birds, is essential for maintaining metabolic stability. Maintaining optimal blood glucose levels may support egg production by reducing the risk of metabolic disorders, such as fatty liver syndrome, and enhancing glucose availability for ovarian follicle development and eggshell matrix synthesis. Abdelkader *et al* (2023) found that plasma glucose significantly increased in all levels of curcumin (50, 75,100 mg/kg diet) compared with the control group.

Minerals Profile (Calcium, Phosphorus, and Ca/P ratio)

Results in Table 4 showed that supplementing laying hen diet with 2 or 3 g Tur/kg diet significantly increased Ca (18.7 and 16.7%)and P (13.5 and 16.7%), consequently enhanced Ca/P ratio in blood compared to the control group. All treatments maintained physiologically appropriate Ca/P ratios (3.30–3.55), with the 3g/kg turmeric group achieving the highest ratio (5.3% vs control), which is essential for optimal eggshell formation (p=0.063).According to Liu *et al.* (2020), lower feed consumption, increased water consumption, and decreased blood calcium levels collectively contribute to a drop in egg quality. Our results align with those documented by Liu *et al*. (2024). Discrepancies observed in different research may be attributed to variations in plant chemical structure, supplementation levels, application methods, bird species, housing conditions, and bioactive components (Hippenstiel *et al*.,2011; Attia and Al-Harthi, 2015; Attia *et al*., 2018; Khalifah *et al*., 2021b).

Plasma Lipid Profile:

The results of Table 5 revealed that the plasma lipid profile, including total lipids, total cholesterol, LDL, HDL, and the HDL/LDL ratio, was markedly influenced by dietary supplementation with turmeric (Tur) and curcumin (Cur).Hens receiving diets enriched with varying amounts of Tur or Cur showed a significant reduction in plasma total lipids and an increase in HDL levels compared to those on the basal diet. Specifically, feeding hens diet contained 3 g Tur/kg diet due to significantly decrease total cholesterol compared with control and 1 g Tur/kg groups. Moreover, dietary inclusion of 2 or 3 g Tur/kg or 150 mg Cur/kg significantly boosted HDL concentrations and improved the HDL/LDL ratio relative to the control group. Biochemical blood parameters serve as reliable indicators of physiological and nutritional status in birds and mammals, often reflecting overall animal welfare, as noted by Alagawany and El-Hack (2015). The observed improvements in lipid profile traits suggest that Tur and Cur positively affect lipid metabolism. Moreover, dietary inclusion of 2 or 3 g Tur/kg or 150 mg Cur/kg significantly boosted HDL concentrations and improved the HDL/LDL ratio relative to the control group. Liu *et al*. (2020) who found no significant changes in lipid profile on laying hens augmented by Cur in contrast to untreated set under extreme stress, they align with findings by Fawaz *et al*. (2023) found that Tur powder decrease significantly cholesterol levels in contrast to untreated set The observed modulation of lipid profiles in this study may stem from the antioxidant and polyphenolic compounds abundantly present in both turmeric and curcumin.

Serum Antioxidant and Lipid Peroxidation Status

Data for the biochemical constituents of serum TAC and lipid peroxidation status (MDA) of Gimmizah laying hens are presented in Table 5. The study reveals a significant impact of dietary turmeric and curcumin supplementation on TAC and MDA. Supplied laying hens' diet with 3g Tur/kg showed the highest TAC activity compared to other groups, which had no significant differences among them Malondialdehyde (MDA) levels decreased progressively with turmeric doses 2g Tur/kg, reaching a 30% reduction (0.91 mg/dl) at 150 mg/kg turmeric versus control (1.30 mg/dl).

A study by Liu *et al*. (2020) observed that administering Cur with a dosage of 150 mg/kg improved antioxidant activity. Notably, there was an enhancement in the synthesis of both glutathione peroxidase and superoxide dismutase, accompanied by a reduction in serum MDA levels ($P< 0.05$).Furthermore, quails supplemented with 200 mg/kg of Cur increased antioxidant activity and improved lipid metabolism (Liu *et al*., 2024). One of the first lines of defense against free radicals in the body is the enzymatic antioxidant markers, which include catalase, superoxide dismutase, and glutathione peroxidase (Akbarian *et al*., 2016). MDA, a byproduct of lipid peroxidation occurring in the unsaturated fatty acids of phospholipids, contributes to cellular damage.

Cur suppresses the synthesis of oxygen-based reactive substances and nitric oxide in macrophages (Joe and Lokesh, 1994; Sreejayan and Rao, 1997). Research has demonstrated that Cur possesses a robust antioxidant impact, which is attributed to its structural makeup. According to Kaneko and Baba (1999), the Curcumin phenolic structure can sequester free radicals and create potent, stable anthraquinones. This study demonstrates that Cur markedly enhances total antioxidant activity by reducing MDA levels. Free radical scavenging and antioxidant enzyme stimulation may be the mechanism by which Cur achieves its protective benefits (Manju *et al*., 2012; Reddy and Lokesh, 1992).

Immune Indices

Results in Table 5 indicate that dietary supplementation with turmeric or curcumin has a significant effect on immunoglobulin levels (IgG and IgM). Hens fed diets containing 2 or 3 g Tur/kg or 150 mg Cur/kg exhibited significantly higher IgG and IgM concentrations compared to the control group. After receiving injections of sheep red blood cells, Tur powder boosts total Ig and IgG concentrations in layers, hence enhancing their immunity (Arshami*etal*., 2013). Similarly, Alagawany *et al*. (2016) observed elevated serum IgG and IgM in rabbits supplemented with 2, 4, or 6 g/kg of curcumin, suggesting a broad immunostimulatory role. In heat-stressed laying hens, Liu *et al.* (2020) reported increased serum immunoglobulin levels across all curcumin-supplemented groups. Zhu *et al*. (2014) observed that Cur possesses qualities that help boost immunity and protein metabolism, in addition to having protective effects on cells. These benefits can be achieved by enzymatic and non-enzymatic methods. Increased serum globulin levels may boost immunity, partly due to bioactive compounds like carotenoids enhancing immune function (Chew and Park, 2004; Rajput *et al*., 2013). Collectively, these findings support the hypothesis that curcumin modulates humoral immunity in laying hens by increasing serum immunoglobulin levels.

Plasma Estrogen, Progesterone, Estrogen/Progesterone Ratio

Data for the impact of Curcumin and turmeric supplementation on plasma estrogen (E_2), progesterone (P_4), and E_2/P_4 ratio are shown in Table 5. Laying hens receiving diets supplemented with either 2 or 3 g Tur/kg or 150 mg Cur/kg showed significantly ($P<0.05$) higher plasma E_2 and E_2/P_4 ratio compared to the control group. The other diets which displayed intermediate. Among these hormonal metrics, the E_2/P_4 ratio is regarded as a more reliable marker for understanding the hormonal regulation of egg production than evaluating each hormone individually, as supported by research (Holt *et al*., 1983; Leszczyński *et al*., 1983). This ratio offers a clearer reflection of the ovarian follicle development process.

Additionally, E_2 has a feedback effect on the hypothalamus and pituitary to promote follicular development (Tarumi *et al*., 2014). The amount of development of eggs produced is directly related to the ratio of E_2 to P_4, because estrogen activates liver cells to form egg yolk and thus form follicles in the hen’s ovary and their multiplicity, thus increasing the rate of egg production. However, curcumin's potential effectiveness may be limited due to its poor bioavailability. As noted by Goswami *et al*. (2018), curcumin demonstrates low systemic absorption and undergoes rapid metabolism after oral administration, which restricts its broader clinical and functional applications.

Economical Efficiency

It was calculated based on the prevailing market prices of feed ingredients, dietary additives, and fertile eggs during the experimental period in 2022, as presented in Table 6. The results indicated that hens provided with 3 g/kg of turmeric achieved the highest egg production (60.09 eggs /day) and net revenue (293.03 LE), leading to superior economic efficiency (1.56) and relative efficiency (143.12%).

Supplementation with curcumin at 150 mg/kg also improved performance and efficiency, albeit slightly less effectively than turmeric. Feed consumption and costs were generally consistent across all groups. In summary, the addition of turmeric at 3 g/kg proved to be the most beneficial, enhancing profitability through increased egg production and improved feed utilization.

CONCLUSION

Using turmeric (Tur) as row material is better than the active component curcumin (Cur) in enhancing productive performance, egg quality, and biochemical parameters in laying hens. Further research is warranted to explore alternative curcumin delivery systems, such as nanoparticle-based formulations and encapsulation techniques, to improve its alternative curcumin delivery systems.

Table (1): Ingredient and chemical composition of the experimental basal diet for Gimmizah laying hens.

Ingredients	**%**
Yellow corn	66.33
Soybean meal (48%CP)	24.20
Limestone	7.50
Dicalcium phosphate	1.32
Vit+Min Premix[1]	0.25
NaCl	0.25
DL-methionine	0.15
Total	100
Calculated composition,%	
Crude protein (%)	16.97
ME, kcal/Kg	2777
C/P ratio	163.6
Methionine, %	0.39
Methionine +Cystine,%	0.67
Lysine, %	0.80
Calcium, %	3.10
Phosphorus available, %	0.45
Values (AOAC, 2000) Analyzed	
Dry matter, %	90.73
Crude protein, %	16.97
Ether extrac, %	2.45
Crude fibre, %	3.96
Ash, %	6.37
Nitorgen free extract, %	60.98

[1]Vit+Min mixture provides per kilogram of diet: vitamin A, 12000 IU; vitamin E, 10 IU; menadione, 3 mg; Vit. D_3, 2200 ICU; riboflavin, 10 mg; Ca pantothenate, 10 mg; nicotinic acid, 30mg; choline chloride, 500 mg; vitamin B_{12}, 10 µg; vitamin B_6, 1.5 mg; vitamin B_1, 2.2 mg; folic acid, 1 mg; biotin, 50 µg. Trace mineral (milligrams per kilogram of diet): Mn, 60; Zn, 50; Fe, 30; Cu, 10; Se, 0.10;Anti oxidant, 3 mg.

Table (2) : Effect of dietary turmeric and curcumin on some productive performance of Gimmizah laying hens.

Criteria	**Treatments**							**SEM**	**P Value**
	Control	**Tur g/kg diet**			**Cur mg/kg diet**				
		1	**2**	**3**	**50**	**100**	**150**		
Egg production,(%)	59.08^{c}	65.71^{abc}	68.04^{ab}	71.54^{a}	63.65^{bc}	66.24^{ab}	67.7^{ab}	0.90	0.000
Egg weight, (g)	48.90	52.03	52.52	53.40	49.67	50.68	52.60	0.56	0.061
Egg mass, (g/hen/d)	28.89^{c}	34.19^{ab}	35.73^{ab}	38.20^{a}	31.61^{bc}	33.57^{b}	35.6^{ab}	0.51	0.000
Feed intake,(g/hen/d)	118.8	116.7	115.9	115.6	114.9	114.3	114.1	1.15	0.059
FCR, (g feed/g egg mass)	4.11^{a}	3.41^{b}	3.24^{b}	3.24^{b}	3.64^{b}	3.40^{b}	3.20^{b}	0.06	0.000

[a, b ,c] :Means within each row that have no similar letter(s) are significantly different (P ≤ 0.05).
Control = fed basal diet without any supplementation. Tur =turmeric,Cur = curcumin, SEM = Standard error for means, P Value= Probability level.

Table (3): Effect of dietary turmeric and curcumin on egg quality of Gimmizah laying hens.

Criteria	Treatments							SEM	P Value
	Control	Tur g/kg diet			Cur mg/kg diet				
		1	2	3	50	100	150		
Shape index	75.5	75.8	76.8	72.2	76.4	74.8	75.2	0.85	0.066
Yolk weight (%)	30.56	29.49	31.50	31.34	30.96	31.06	31.80	0.78	0.490
Albumin (%)	59.39	60.86	58.96	59.28	59.17	58.88	58.11	0.79	0.393
Shell weight (%)	10.08	9.67	9.56	9.40	9.90	10.08	10.10	0.31	0.581
Shell thickness (mm)	0.43	0.40	0.43	0.43	0.42	0.44	0.42	1.22	0.645
yolk index	39.67	40.37	39.04	38.70	39.76	39.77	38.98	0.85	0.860
Yolk color score	6.78^{b}	6.78^{b}	7.56^{ab}	7.78^{a}	8.00^{a}	8.33^{a}	8.56^{a}	0.35	0.003

$^{a, b}$:Means within each row that have no similar letter(s) are significantly different ($P \leq 0.05$).
Control = fed basal diet without any supplementation. Tur =turmeric,Cur = curcumin, SEM = Standard error for means, P Value= Probability level.

Table (4): Effect of dietary turmeric and curcumin on some blood biochemical constituents of Gimmizah laying hens.

Criteria	Treatments							SEM	P Value
	Control	Tur g/kg diet			Cur mg/kg diet				
		1	2	3	50	100	150		
Total protein (g/dl)	5.46^{bc}	5.84^{ab}	6.07^{a}	6.08^{a}	5.46^{bc}	5.50^{b}	5.77^{ab}	0.16	0.001
Albumin (g/dl)	3.24^{ab}	3.15^{ab}	3.06^{b}	3.22^{ab}	3.32^{a}	3.28^{ab}	3.24^{ab}	0.06	0.000
Globulin (g/dl)	2.22^{cd}	2.69^{bc}	3.01^{ab}	2.86^{a}	2.14^{d}	2.22^{cd}	2.53^{bc}	0.11	0.000
AST (U/L)	48.74^{a}	39.64^{bc}	39.75^{bc}	36.19^{c}	48.12^{a}	44.56^{ab}	44.56^{ab}	2.95	0.002
ALT (U/L)	19.74^{a}	15.52^{b}	12.27^{c}	12.42^{c}	19.61^{a}	14.17^{b}	14.80^{b}	1.55	0.001
Glucose (mg/dl)	162.7^{ab}	162.8^{ab}	127.9^{c}	128.6^{c}	166.7^{a}	148.4^{b}	130.6^{c}	5.96	0.000
Calcium (mg/dl)	21.40^{e}	22.47^{e}	24.97^{ab}	25.41^{a}	21.78^{e}	23.60^{cd}	24.09^{c}	0.39	0.000
Phosphorous(mg/dl)	6.36^{d}	6.60^{c}	7.22^{a}	7.16^{a}	6.59^{c}	6.97^{b}	6.93^{b}	0.05	0.000
Ca/P ratio	3.37^{ab}	3.40^{ab}	3.46^{ab}	3.55^{a}	3.30^{b}	3.39^{ab}	3.48^{ab}	0.06	0.063

$^{a, b ,c, d,e}$:.Means within each row that have no similar letter(s) are significantly different ($P \leq 0.05$).
Control = fed basal diet without any supplementation. Tur =turmeric,Cur = curcumin, SEM = Standard error for means, P Value= Probability level.

Table (5): Effect of dietary turmeric and curcumin on plasma lipid profile, serum antioxidant, lipid peroxidation status, immunity and plasma sex hormones of Gimmizah laying hens.

Criteria	Treatments							SEM	P Value
	Control	Tur g/kg diet			Cur mg/kg diet				
		1	2	3	50	100	150		
Lipid profile									
Total Lipids (g/dl)	6.98^{a}	6.45^{b}	5.17^{d}	5.11^{d}	6.37^{b}	5.74^{c}	5.14^{d}	0.08	0.000
Cholesterol (mg/dl)	176^{a}	176.0^{a}	166.7^{ab}	147.0^{b}	173.7^{ab}	169.3^{ab}	173.7^{ab}	7.92	0.086
HDL (mg/dl)	46.3^{b}	47.0^{b}	45.0^{b}	54.3^{a}	44.7^{b}	42.3^{b}	47.3^{b}	1.05	0.000
LDL (mg/dl)	120.3^{a}	118.3^{a}	88.7^{c}	97.3^{bc}	108.0^{b}	103.7^{b}	98.0^{bc}	5.16	0.018
HDL/LDL ratio	0.38^{b}	0.40^{b}	0.51^{a}	0.56^{a}	0.41^{b}	0.41^{b}	0.48^{b}	0.23	0.000
Antioxidant status									
TAC (mg/dl)	386.7^{b}	399.0^{b}	399.0^{b}	488.0^{a}	404.0^{b}	404.8^{b}	409.0^{b}	5.68	0.000
MDA (mg/dl)	1.30^{a}	1.11^{d}	0.91^{f}	0.99^{e}	1.21^{b}	1.16^{bc}	1.14^{cd}	0.02	0.000
Immunity									
IgG (mg/dl)	9.95^{e}	11.32^{cd}	12.44^{ab}	13.00^{a}	10.30^{de}	10.66^{cde}	11.45^{bc}	0.334	0.000
IgM (mg/dl)	1.18^{d}	1.20^{cd}	1.24^{ab}	1.25^{a}	1.21^{cd}	1.20^{cd}	1.22^{bc}	0.007	0.000
Hormones									
P_4 (ng/ml)	0.603^{ab}	0.570^{bc}	0.617^{a}	0.540^{c}	0.607^{ab}	0.617^{a}	0.637^{a}	0.011	0.000
E_2 (ng/ml)	0.607^{d}	0.664^{cd}	0.771^{bc}	0.956^{a}	0.681^{cd}	0.710^{cd}	0.833^{b}	0.033	0.000
E_2/P_4 ratio	0.993^{d}	1.165^{cd}	1.249^{b}	1.770^{a}	1.122^{cd}	1.151^{cd}	1.317^{c}	0.062	0.000

a, b ,c, d ,e,f:.Means within each row that have no similar letter(s) are significantly different ($P \leq 0.05$).
Control = fed basal diet without any supplementation. Tur =turmeric,Cur = curcumin, SEM = Standard error for means, P Value= Probability level.E_2= Estrogen ,P_4=Progesterone

Table (6): Effect of dietary turmeric and curcumin on economical efficiency of Gimmizah laying hens during 32-44 weeks of age.

Criteria	Treatments						
	Control	Tur g/kg diet			Cur mg/kg diet		
		1	2	3	50	100	150
Total egg No/ hen	49.63	55.2	57.15	60.09	53.47	55.64	56.88
Price of one Hatching egg (L.E.)	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Total revenue (L.E.)	397.04	441.6	457.20	480.72	427.76	445.12	455.04
FI/day /hen (g)	118.8	116.7	115.9	115.6	114.9	114.3	114.1
Total feed intake (kg.)	9.98	9.80	9.74	9.71	9.65	9.60	9.58
Price/kg feed (L.E.)	19.00	19.11	19.22	19.33	19.10	19.20	19.30
Total feed cost (L.E.)	189.62	187.28	187.20	187.69	184.32	184.32	184.89
Net revenue (L.E.)	207.42	254.32	270.00	293.03	243.44	260.80	270.15
Economic efficiency E.E	1.09	1.36	1.44	1.56	1.32	1.41	1.46
Relative EE (%)	100.00	124.77	132.11	143.12	121.10	129.36	133.94

Control = fed basal diet without any supplementation. Tur =turmeric Cur =curcumin
L.E. = Egyptian pound. Price of one 1 kilogram of turmeric=110 LE. Price of one 1 kilogram of curcumin= 2000 LE. According to local price of different ingredients available in Egypt at the experimental period.
1. Total egg number /hen day.2. Price/egg (assuming 8 LE/egg).
3. Total revenue (LE) = (1 × 2).4. Feed intake /day /hen (g) =
5. Total feed intake (kg) =6. Price /kg feed (LE) =
7. Total feed cost (LE) = (5×6).8. Net revenue (LE) = (3 – 7).
9. Economic efficiency (EE) = Net revenue/total feed cost. (8/ 7).

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الملخص العربى

تأثير إضافة الكركم و الكركمين فى العليقة على الصفات الانتاجية و التناسلية لدجاج الجميزة البياض

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أجريت هذه الدراسة لمعرفة مدى تاثيرإضافة الكركم والكركمين فى علائق الدجاج البياض على تحسين أداء دجاج الجميزة و بعض الصفات الفسيولوجية و المناعية ، استخدم فى هذه الدراسة عدد 168 دجاجة عمر 32 أسبوع من سلالة الجميزة. تم وزن الطيور فردياً و قسمت عشوائياً إلى سبع مجموعات كل مجموعة تتكون من 24 دجاجة فى اقفاص فردية فى عنبر يعمل بالنظام المفتوح حتى نهاية التجربة عند 44 أسبوع. استخدمت المجموعة الأولى كمجموعة مقارنة (كنترول) و تم تغذيتها على العليقة الأساسية بدون إضافات و المجموعة الثانية و الثالثة و الرابعة تمت تغذيتها على العليقة الأساسية مضاف إليها الكركم بمعدل 1 ,2, 3جم / كجم علف على الترتيب أما المجموعة الخامسة و السادسة و السابعة فتم تغذيتها على العليقة الاساسية مضافاً إليها الكركمين بمعدل50 ،100 ،150 ملجم / كجم علف على الترتيب .أوضحت نتائج التجربة أن الدجاج المغذى على 3جم/كجم ثم 2 جم /كجم من الكركم أو 150 ملجم كركمين أعطوا أفضل نتائج لصفات انتاج البيض و كتلة البيض و الكفاءة التحويلية للعلف مقارنة بالمجاميع الأخرى. ايضا كان للاضافات الغذائية المختلفة للعليقة الأساسية تاثيرا معنويا على تحسين مضادات الأكسدة و كفاءة الكبد وصور الدهن فى الدم مقارنة بالكنترول, كما وجد ان لها تاثيرا معنويا على هرمون الاستروجين والنسبة بين هرمونى الاستروجين والبروجستيرون مقارنة بالكنترول.

وقد لخصت الدراسة الى ان اضافة 3جم أو2جم كركم أو 150 ملجم كركمين لكل كجم علف يؤدوا إلى تحسن فى الصفات الانتاجية و التناسلية و المناعية خلال مرحلة الانتاج لدجاج الجميزة البياض فضلا عن الكفاءة الاقتصادية .

و من المقترح أنه يمكن إضافة الكركم أو الكركمين فى العليقة حتى مستوى 3جم أو 150 ملجم لكل كيلو جرام علف على الترتيب للحصول على افضل اداء انتاجى لدجاج الجميزة البياض.