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Thyme (*Thymus vulgaris*) as a Natural Feed Additive in Poultry Nutrition: Enhancing Performance, Health, and Carcass Traits

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ABSTRACT

The worldwide demand for poultry products is on the rise, thus emphasizing the necessity of natural additives in feed that boost productivity but do not compromise animals' health and food safety. Thyme (*Thymus vulgaris*) is a medicinal and culinary herb that has attracted attention as a phytogenic feed additive because of its bioactive compounds such as thymol and carvacrol. This review aims to summarize the impact of thyme supplementation in poultry, namely in broilers, layers, and quail, through leaves, powders, essential oils, and aqueous extracts. Thyme has been shown to improve growth performance, feed efficiency, and carcass traits at inclusion rates of 0.5%-2% for powders and 0.5%-1% for essential oils. Thyme supplementation influences reproductive performance, egg quality, and semen parameters; moreover, it also works as an immune modulator by increasing IgG, IgM, interferon-gamma, and interleukin-10. Antioxidant defense is strengthened through enhanced activities of glutathione, superoxide dismutase, and glutathione S-transferase, along with reduced levels of malondialdehyde. Additionally, thyme showed favorable effects on serum lipid profile and gut health by stimulating protective species of *Lactobacillus* and suppressing pathogens (such as *Escherichia coli*). Mechanistic data suggest regulation of inflammatory cytokines and intestinal barrier genes. Thyme is a promising candidate for replacing antibiotics as growth promoters in tropical poultry systems, at levels of 0.5%-2% thyme powder and 100-200 mg/kg essential oil. To fully realize the potential of thyme as a sustainable alternative to antibiotics in poultry production, future studies should explore optimal dosing, mechanistic studies of the target site of action, stress mitigation capacity, long-term production impacts, and economic viability.

Keywords: antioxidant activity; immune modulation; phytogenic; poultry performance; thyme

INTRODUCTION

The global population is growing at an unprecedented rate, thus increasing the demand for poultry products significantly. Consequently, the poultry sector has adopted various strategies to achieve high productivity while meeting food quality and safety requirements. Previously, antibiotics were used extensively in the poultry industry for prophylactic treatment of bacterial infections and as a growth promoter. Nonetheless, their widespread and sometimes inappropriate applications have been significantly linked to the development and dissemination of antimicrobial resistance in a vertical perspective, posing a major public health threat globally (Abreu *et al*., 2023; Abd El-Aziz *et al*., 2024). After the prohibition or restriction of antibiotic growth promoters (AGPs) in the poultry diet, producers have often reported a decrease in productive performance, such as lower body weight gain, feed efficiency, and higher feed conversion ratio (Yang *et al*., 2024). Therefore, great efforts have been devoted to natural feed additives as possible substitutes for AGPs. These include probiotics (Cufadar *et al*., 2024), prebiotics (Youssef *et al*., 2023), synbiotics (Youssef *et al*., 2024), essential oils, herbal bioactive compounds, and phytogenic blends (El-Saadony *et al*., 2023; El-Sabrout *et al*., 2026; Buonaiuto *et al*., 2025), which have demonstrated growth-promoting, antimicrobial, and health-enhancing properties. Apart from microbial control, oxidative degradation of lipids in poultry poses another risk associated with metabolic disease and cardiovascular abnormalities. As a result, antioxidants (both natural and synthetic ones) are significant aspects in preventing lipid peroxidation (Lobo *et al*., 2010; Wu *et al*., 2024). In this regard, a high demand has arisen for medicinal plants due to their lower cost, availability, and richness in bioactive compounds with higher free radical-scavenging ability (Hesabi Nameghi *et al*., 2019).

Thyme (*Thymus vulgaris* L.), a perennial herb in the Lamiaceae family, is one of these plants that has long been valued for its nutritional and medicinal properties (Iftikhar *et al*., 2023). One of the most popular herbal remedies and culinary spices in the world is thyme that is native to the Mediterranean region. Phenolic compounds, especially thymol (2-isopropyl-5-methylphenol) and carvacrol (5-isopropyl-2-methylphenol), which have been thoroughly investigated for their positive effects on human and animal health, are primarily responsible for its biological activity (Khan *et al*., 2012). According to Zambonelli *et al*. (2004) and Hazzit *et al*. (2006), the concentrations of the primary bioactive components of thyme, specifically thymol and carvacrol, exhibit significant variation based on plant chemotype, geographic origin, harvest stage, and extraction technique.

These qualities have led to a growing use of thyme as a natural feed additive in chicken diets. Enhanced digestive activity, improved nutrient absorption and metabolism, and modulation of the gut microbiota have all been linked to improvements in broiler growth performance, feed efficiency, and overall economic return after thyme supplementation (Abd El-Hack *et al*., 2016; Deeb *et al*., 2024). Thyme essential oil's potential as a functional feed ingredient in poultry nutrition is further supported by its strong antioxidant (Grigore *et al*., 2010), antimicrobial (Windisch *et al*., 2008), and anti-inflammatory properties (Fachini-Queiroz *et al*., 2012).

These advantages are supported by experimental data from grill production systems. For example, Hassan and Awad (2017) found that adding 5% thyme powder to the diet greatly improved broiler growth performance and immune response. Almremdhy and Al-Khafaji (2020) also showed that thyme oil added to drinking water had positive effects on growth performance and immune function. Additionally, Nameghi *et al*. (2022) demonstrated that feeding grill chickens a blend of thyme and rosemary powder (0.75 g/kg) enhanced their growth performance, carcass characteristics, and antioxidant status.

Overall, the growing body of evidence indicates that thyme is a promising phytogenic feed additive with growth-promoting, immunomodulatory, and antioxidant properties. This review aims to comprehensively evaluate the effects of thyme leaves, powder, and essential oil on different poultry species, including broiler, layers, and quail, across a range of inclusion levels (typically 0.5-2 g/kg feed for thyme powder and 100-200 mg/kg for thyme essential oil).

METHODOLOGY

Electronic databases of published scientific literature were methodically consulted for this review. The PubMed, Scopus, and Google Scholar databases were searched for research on thyme poultry nutrition, including its use as leaves, powder, and essential oil. This paper reviewed a total of 62 references from 47 different journals and scholarly sources. Of these sources, 38 are indexed in PubMed, 17 in Scopus, and 7 were retrieved via Google Scholar (primarily regional and specialized agricultural journals). The publication years of the cited literature range from 2003 to 2026, with a high percentage of the references published within the last decade to ensure the inclusion of the most current scientific advancements. By manually cross-referencing the retrieved articles, more pertinent publications were found. Combinations of the following keywords were used to search the literature: "thyme," "*Thymus vulgaris*," "active compounds," "mechanism of action," "physicochemical properties," "recommended supplementation levels," "performance," "growth performance," "feed efficiency" and "carcass traits," "reproduction and egg quality," "blood biochemical parameters," "immune response," "antioxidant status," and "gut health" in relation to broilers, layers, and quails.

POTENTIAL EFFECTS OF THYME (*Thymus vulgaris*) SUPPLEMENTATION IN POULTRY NUTRITION

Research evidence indicates that dietary supplementation with thyme (*Thymus vulgaris*) exerts multiple beneficial effects in poultry production. These effects, summarized in Figure 1 and Figure 2, include improvements in growth performance, carcass characteristics, blood biochemical parameters, immune response, gut health, and overall economic efficiency.

Growth Performance in Response to Thyme Supplementation

Table 1 provides a thorough summary of experimental research assessing the impact of supplementing poultry with thyme-based additives on growth performance. The growth performance of broiler chickens can be positively impacted by dietary supplementation with thyme, either as leaf powder or essential oil, according to numerous studies. However,

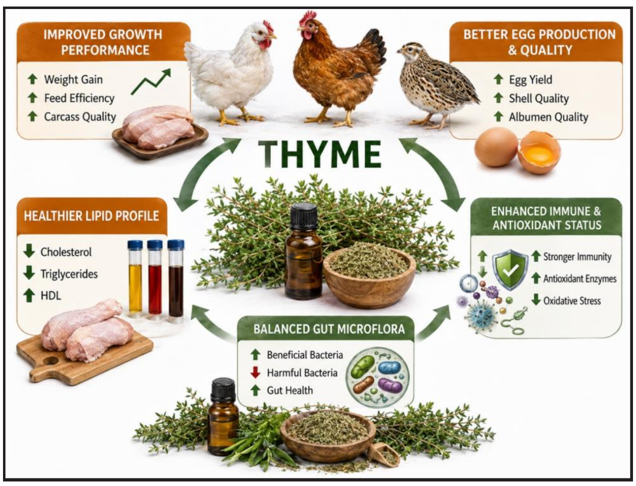

Figure 1. Potential benefits of thyme supplementation in poultry nutrition (created by AI and edited by authors).

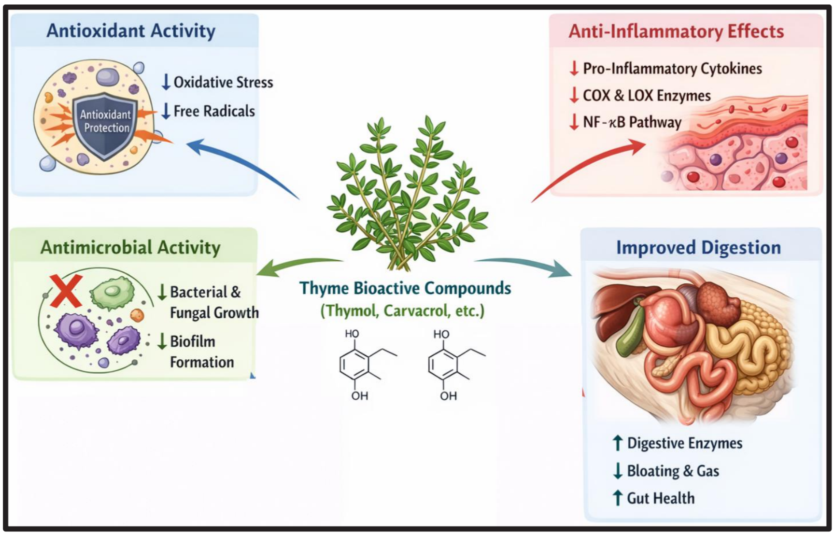

Figure 2. Mechanisms of action of Thyme's bioactive components (created by AI and edited by authors)

responses seem to be dose-dependent and depend on the type of supplementation. According to Deeb *et al*. (2024), supplementing with thyme leaf powder (TLP) at concentrations between 1 and 3 g/kg increased body weight and daily body weight gain (DBWG) at various growth stages. Birds receiving 3 g TLP/kg exhibited the highest body weight at 15 days of age, while inclusion levels of 1 and 2 g/kg resulted in superior final body weight and DBWG over the entire rearing period (days 1-38). Improvements in feed conversion ratio (FCR) were particularly evident at inclusion levels of 2 and 3 g TLP/kg, indicating enhanced feed efficiency.

At higher inclusion levels, thyme powder has also been shown to consistently promote growth. In broilers fed diets supplemented with 5 g/kg thyme powder, Hassan and Awad (2017) found significant increases in body weight, body weight gain, and feed intake. Similarly, despite no discernible changes in feed intake, Abdel-Wareth *et al*. (2012) showed that supplementing a diet with 15 or 20 g/kg of thyme significantly increased body weight gain and improved FCR when compared to a basal control diet. The observed improvements were ascribed to the bioactive qualities of thyme because all experimental diets were isoenergetic and isonitrogenous.

On the other hand, at lower inclusion levels, some studies have found inconsistent or limited effects. The final body weight, body weight gain, FCR, and protein efficiency ratio were all marginally improved by dietary thyme leaf powder supplementation at 0.5%–1.5%, according to Abdel-Ghaney *et al*. (2017). However, these improvements were not statistically significant ($p>0.05$). Similarly, Ocak *et al*. (2008) found that in Ross 308 broilers aged 7 to 35 days, supplemented with 0.2% thyme leaf (equivalent to 70 mg thymol/kg diet) had no discernible effect on body weight gain, feed intake, or FCR. Notably, these differences among studies are likely due to the potency of the thyme used, specifically the concentration of active compounds like thymol, and the timing of when the supplement was introduced to the chicks' diet. Scientifically, if the dosage or the bird's age at the start of the study is not optimal, the thyme may fail to reach the biological threshold necessary to produce a measurable impact.

Thyme essential oil (TEO) has generally produced more consistent responses at lower inclusion rates compared with powder forms because it provides a highly concentrated, standardized dose of bioactive phenols like thymol and carvacrol, whereas powder forms are subject to the natural variability of plant fiber, soil quality, and harvest conditions. Because the oil isolates these active metabolites from the inert plant matrix, it offers superior bioavailability and more predictable physiological effects. Furthermore, TEO can be easily emulsified or encapsulated to ensure uniform distribution and protection during digestion, allowing for precise, potent supplementation that avoids the bulk and instability associated with raw botanical powders. Adam *et al.* (2020) reported that supplementation with thyme oil at 100 or 200 mg/kg significantly improved final body weight, body weight gain, and FCR in Arbor Acres broilers, with the greatest response observed at 200 mg/kg, as at this inclusion level, feed intake was notably decreased, indicating improved growth efficiency. Comparable results were reported by Almremdhy and Al-Khafaji (2020), who administered thyme oil via drinking water (0.3 mL/L) and observed significant ($p<0.05$) improvements in body weight, weight gain, and FCR, accompanied by reduced feed intake.

The phenolic components of thyme, thymol, and carvacrol, which have potent antimicrobial and antioxidant properties that may improve digestion, nutrient absorption, and gut microbial balance, have also been linked to the growth-promoting benefits of thyme (Cross *et al*., 2007; Hoffman-Pennesi and Wu, 2010). Thyme powder or essential oils have been shown to improve broiler growth performance in several previous studies (Toghyani *et al*., 2010; Foroughi *et al*., 2011; El-Sabrout *et al*., 2023; Soliman *et al*., 2024).

Under environmental stress, thyme supplementation appears particularly effective. Attia *et al.* (2017) demonstrated that dietary thyme oil supplementation at 1.0-2.0 g/kg significantly improved

Table 1. Previous reports showing the effect of dietary thyme on performance traits, reproductive traits, and economic efficiency in poultry

Study	Species (age)	Thyme form[2]	Dose	Key outcomes[1]
Deeb *et al.* (2024)	Broilers, Ross 308 (1-38 d)	TLP	1-3 g/kg diet	Higher BW at 15 d with 3 g/kg; higher final BW and DBWG with 1-2 g/kg; FCR improved at 2–3 g/kg; effects were dose- and age-dependent.
El-Hadad *et al.* (2024)	Male Gimmizah chickens	TLAE	4 mL/10 L water	Improved sperm motility, morphology, velocity, and kinetic parameters.
El-Hadad *et al.* (2024)	Female Gimmizah chickens	TLAE	4 mL/10 L water	Increased egg yield, egg weight, chick weight, Haugh unit, shape index, and albumen/yolk indices.
Hassan *et al.* (2024)	Broilers, Ross 308 (1-35 d)	TP	1.0% diet	Improved BWG and FCR vs antibiotic control; effects were inferior to other treatments.
Maulod *et al*. (2022)	Japanese quails (1-35 d)	TP	0.5-1.0% diet	BW and BWG increased; FI unchanged, indicating improved growth efficiency.
Nameghi *et al*. (2022)	Broilers, Ross 308 (14-42 d)	TP	0,38%	ADG (+5.62%) and FCR (+10.37%) improved vs positive control diet.
Adam *et al*. (2020)	Broilers, Arbor Acres (1-35 d)	TP/TEO	2.5-5 g/kg	All treatments improved growth; 200 mg/kg TEO showed greatest BWG and FCR improvement with reduced FI, indicating higher feed efficiency.
Almremdhy and Al-Khafaji (2020)	Broilers, Ross 308 (1-35 d)	TO	0.3 mL/L water	Significant improvement in growth traits and immune indicators; FI decreased with improved FCR.
Hesabi Nameghi *et al*. (2019)	Broilers, Ross 308 (1-42 d)	EO blend (thyme–peppermint–eucalyptus)	150 ppm water	BWG (+11.73%), FCR (+10.81%), and production index (+24.13%) improved vs control.
Khafar *et al.* (2019)	Broilers, Ross 308 (1-42 d)	TEO	150, 200 mg/kg	BWG and FI increased; FCR reduced; thyme mitigated heat stress effects.
Kheiri *et al*. (2018)	Japanese quails (7-35 d)	TP	2 g/kg diet	No significant effects on BW or FI; slight, non-significant improvement in FCR.
Attia *et al*. (2017)	Broilers, Arbor Acres (1-28 d)	TO	1.0-2.0 g/kg	FCR significantly improved at 1.0 g/kg; moderate inclusion was more effective under heat stress
Abdel-Ghaney *et al*. (2017)	Broilers, Cobb (1-35 d)	TLP	0.5, 1.0, 1.5% diet	Slight improvements at 0.5% inclusion; differences were not statistically significant.
Hassan and Awad (2017)	Broilers, Cobb 500 (1-42 d)	TP	5 g/kg diet	Significant increases in BW, BWG, and FI indicate enhanced nutrient utilization.
Hassan and Awad (2017)	Broilers, Cobb 500 (1-42 d)	TP	2-8 g/kg diet	2-5 g/kg optimized profitability; 8 g/kg reduced net revenue due to increased feed cost; 5 g/kg showed the best economic return.
Abdel-Wareth *et al*. (2012)	Broilers, Ross 308 (1-42 d)	TP	15-20 g/kg diet	BWG and FCR significantly improved; FI was unaffected by thyme; effects attributed to phytogenic bioactivity in isoenergetic diets.
Khaksar *et al*. (2012)	Japanese quail (1-35 d)	TEO	1 g/kg diet	Significant increase in live BW compared with control.
Ocak *et al*. (2008)	Broilers, Ross 308 (7-42 d)	TL	0.2% diet	No significant effects on BWG, FI, or FCR.

Note: [1]BW, body weight; DBWG, daily body weight gain; FCR, feed conversion ratio; FI, feed intake. [2]TLP: Thyme leaf powder; TP: Thyme powder; TL: Thyme leaves; TEO: Thyme essential oil; TO: Thyme oil; TLAE: Thyme leaf aqueous extract.

FCR in heat-stressed Ross 308 broilers ($p<0.01$). Similarly, Khafar *et al.* (2019) reported that thyme essential oil at 150 or 200 mg/kg mitigated the negative effects of heat stress by improving body weight gain and feed efficiency while reducing FCR. TEO mitigates heat stress by acting through a synergistic multi-pathway mechanism that prioritizes metabolic efficiency and cellular protection. Primarily, its phenolic components, thymol and carvacrol, neutralize reactive oxygen species (ROS) and boost endogenous antioxidant enzymes, preventing the oxidative damage to tissues typically caused by high temperatures. Simultaneously, TEO stimulates the secretion of digestive enzymes and improves intestinal morphology, specifically increasing villus height, ensuring that nutrient absorption remains high even when heat-induced blood flow is diverted from the gut. By suppressing systemic inflammation and downregulating heat shock proteins, TEO reduces the metabolic energy "tax" of the stress response, allowing the animal to redirect its physiological resources toward weight gain and improved feed conversion ratios (Büyükkılıç Beyzia *et al.*, 2020; Mahasneh *et al.*, 2024).

Comparative studies have also shown that thyme (powder) can perform similarly to, or better than, conventional antibiotic growth promoters. Hassan *et al.* (2024) reported that supplementation with thyme (1.0% of diet), ginger (1.0%), or their nanoparticles (0.10%) forms significantly improved body weight gain and FCR compared with a diet containing bacitracin methylene disalicylate. In addition, Hesabi Nameghi *et al.* (2019) observed that thyme–peppermint–eucalyptus essential oil blend administered via drinking water (150 ppm) significantly improved production index, body weight gain, and feed efficiency in broilers. Likewise, Nameghi *et al.* (2022) reported that a combination of thyme and rosemary powders (0.375% each) improved average daily gain and FCR compared with a positive control diet.

In other poultry species, responses to thyme supplementation have been variable. In Japanese quail, Maulod *et al.* (2022) reported that dietary thyme powder at 0.5-1.0% significantly increased live body weight and body weight gain without affecting feed intake. Khaksar *et al.* (2012), similarly reported increased live body weight following supplementation with 1 g/kg thyme essential oil. Conversely, Kheiri *et al.* (2018) found no significant effects of thyme supplementation at 2 g/kg on growth performance or feed intake in Japanese quail. Eidrisha *et al.* (2022) further highlighted species- and dose-dependent variability, reporting that thyme supplementation (5 or 10 g/kg) did not significantly enhance growth performance compared with other herbal additives.

Reproductive Performance and Egg Quality in Response to Thyme Supplementation

Thyme supplementation enhances poultry reproductive performance and egg quality primarily by leveraging its potent antioxidant properties to protect highly metabolic reproductive tissues and lipid-rich egg components (Table 1). The transfer of bioactive phenols, such as thymol and carvacrol, into the egg yolk reduces lipid peroxidation and malondialdehyde (MDA) levels, which maintains the Haugh unit and extends egg freshness. Furthermore, thyme supports shell integrity by improving mineral metabolism and protecting the shell gland's mucosal health, while simultaneously optimizing follicular development in the ovaries and sperm viability in males. By mitigating oxidative stress and inhibiting cholesterol-synthesis enzymes, thyme ensures a more persistent laying rate, improved fertility, and the production of nutritionally superior eggs with lower cholesterol and higher oxidative stability (Yalçın *et al.*, 2020; Hassanpour *et al.*, 2025). Evidence regarding the effects of thyme supplementation on reproductive performance and egg quality in poultry is limited but promising. Male Gimmizah chickens given thyme leaf aqueous extract (TLAE) at a dosage of 4 mL/10 L of drinking water showed notable improvements in semen quality parameters, such as sperm motility, morphological characteristics, velocity, and kinetic traits, according to El-Hadad *et al*. (2024). These results imply that thyme bioactive compounds have a beneficial effect on male reproductive function. Although there were no discernible effects on fertility or hatchability rates, dietary administration of TLAE at 4 mL/10 L significantly increased egg yield, hatched chick weight, and the chick–ovo index in laying hens. These findings suggest that supplementing with thyme may improve early chick performance and reproductive output without negatively impacting reproductive efficiency. Furthermore, a recent study by Ebrahimi *et al.* (2025) reported that adding 0.5% thyme powder to laying hen diet can improve performance and the number of large white follicles, as well as decrease the level of triglycerides and cholesterol in egg yolk and blood serum.

With respect to egg quality, supplementation with TLAE and TEO resulted in marked improvements in several physical and internal egg quality traits; specifically, egg weight, length, width, Haugh unit, and shape index were significantly increased compared with those of the control group (El-Hadad *et al*., 2024; Song *et al*., 2026). Moreover, improvements were observed in albumen weight, height, and index, as well as yolk height and yolk index, indicating an overall enhancement of egg structural quality and freshness. In the same manner, recent findings by Baser *et al*. (2025) demonstrated that supplementing Chukar partridge diets with 50 mg/kg of TEO significantly boosts egg production and mass without compromising performance or mineral balance. These improvements are likely driven by active compounds like thymol and carvacrol, which facilitate better nutrient utilization by enhancing the structural integrity of the intestinal lining, increasing the height of the villi to provide a larger surface area for nutrient uptake, while simultaneously suppressing pathogenic microflora that would otherwise compete for energy. Additionally, they improve the net "bioavailability" of the diet; these compounds ensure that a higher proportion of ingested protein, minerals, and energy is partitioned away from metabolic waste and toward the physiologically demanding process of follicular development and egg formation. Notably, higher doses did not provide additional benefits; instead, they negatively impacted metrics such as eggshell thickness and yolk index, potentially due to impaired nutrient absorption. Consequently, 50 mg/kg appears to be the optimal dosage for enhancing partridge productivity.

Economic Efficiency of Thyme Supplementation

Data are relatively scarce regarding the economic gain of thyme supplementation in poultry production (Table 1). However, in spite of this, the study of Hassan and Awad (2017) has resulted useful information in terms of cost–benefit effect of thyme inclusion on broiler diet. The economic analysis performed by the mentioned authors showed that a high level of thyme powder inclusion (8 g/kg diet) was not economically viable since it resulted in higher costs with feed and net revenue per kilogram of live weight was the lowest. In contrast, broilers fed thyme-supplemented diets with moderate concentrations of thyme (2 or 5 g/kg) were equal to or better than the control group in terms of economic performance; thus, supplementation at a level of 5 g/kg represented the most favorable cost/performance with regard to growth and feed costs as well as overall profitability, emphasizing that experimental optimization for inclusion levels would ensure high economy when using thyme as phytogenic feed additive.

Carcass Traits and Meat Quality in Poultry Fed Thyme-Supplemented Diets

Dietary supplementation with thyme, provided as dried leaves, powder, or essential oil, has been reported to influence carcass characteristics and meat quality in poultry (Table 2). The scale and nature of the changes appear to vary by the dose used and the type of poultry. In broiler chickens, Deeb *et al*. (2024) have indicated that TLP (1-3 g/kg diet) has had minimal influence on most carcass characteristics. There were no dietary treatment differences in the dressing percentage, abdominal fat, and heart gizzard, and distributions of spleen; no linear or quadratic changes were noted as TLP concentration increased. However, liver weight expressed as a percentage of body weight was significantly reduced in birds fed 3 g/kg TLP compared with the control group, suggesting a potential modulatory effect of thyme on hepatic metabolism or metabolic load.

Contrasting results have been reported in other studies. Khaksar *et al.* (2012) demonstrated that supplementation of Japanese quail diets with 1 g/kg TEO significantly increased carcass and breast yields compared with those of the control group. Similarly, Lee *et al.* (2003a) observed that thymol supplementation increased liver weight in broilers at 21 days of age, although this effect was not evident at 40 days. In contrast, Ocak *et al.* (2008) reported no significant effects on carcass weight or dressing percentage in Ross 308 broilers fed diets containing 0.2% thyme leaves up to 42 days of age. Nevertheless, both herbs significantly increased abdominal fat pad weight, indicating a possible trade-off between growth-promoting effects and carcass fat deposition.

Adam *et al.* (2020) further reported that while dressing percentage and relative organ weights were largely unaffected by thyme supplementation, the inclusion of thyme powder (2.5-5 g/kg) or thyme oil (100-200 mg/kg) consistently reduced abdominal fat content in broilers. The lowest abdominal fat values were observed in birds receiving 200 mg/kg thyme oil, suggesting a dose-dependent lipolytic or metabolic regulatory effect. Conversely, no significant changes in carcass characteristics were detected in quail fed diets supplemented with thyme powders at 5 or 10 g/kg (Eidrisha *et al*., 2022).

Hassan *et al.* (2024) reported that dietary supplementation with thyme at 1.0%, as well as thyme and ginger nanoparticle forms at 0.10%, did not significantly affect carcass yield or most organ weights in broilers. However, an increase in the relative weight of the bursa of Fabricius and a reduction in abdominal fat were observed compared with the control group. In addition to carcass traits, thyme, ginger, and their nanoforms positively influenced meat quality attributes, including color, water-holding capacity, and sensory characteristics, with effects comparable to those observed in antibiotic-supplemented birds. Similarly, supplementation with a thyme–peppermint–eucalyptus essential oil blend (100-200 ppm) significantly increased carcass yield and thigh muscle proportion in Ross 308 broilers (Hesabi Nameghi *et al*., 2019). Khaksar *et al*. (2012) found that TEO supplementation significantly

Table 2. Several studies showing the effect of thyme supplementation on carcass traits in poultry

Study	Species (age)	Thyme form[1]	Dose	Key outcomes
Deeb *et al.* (2024)	Broilers, Ross 308 (1-38 d)	TLP	1-3 g/kg diet	No effect on dressing percentage; relative liver weight decreased at 3 g/kg TLP.
Hassan *et al*. (2024)	Broilers, Ross 308 (1-35 d)	TP	1.0% diet	Reduced abdominal fat; increased relative bursa weight; improved meat quality attributes.
Maulod *et al*. (2022)	Japanese quails (1-35 d)	TP	0.5%-1.0% diet	Increased breast, wing, leg, and back percentages in both sexes; dressing percentage increased in females.
Adam *et al*. (2020)	Broilers, Arbor Acres (1-35 d)	TP/TEO	2.5-5 g/kg	Reduced abdominal fat; no significant effects on dressing percentage or internal organ weights.
Hesabi Nameghi *et al*. (2019)	Broilers, Ross 308 (1-42 d)	EO blend (thyme–peppermint–eucalyptus)	150 ppm water	Increased carcass yield and thigh muscle proportion at higher inclusion levels.
Khaksar *et al.* (2012)	Japanese quail (1-35 d)	TEO	1 g/kg diet	Significant increases in carcass and breast muscle percentages.
Ocak *et al.* (2008)	Broilers, Ross 308 (7-42 d)	TL	0.2% diet	No effect on carcass yield; abdominal fat percentage increased.

Note: [1]TLP: Thyme leaf powder; TP: Thyme powder; TL: Thyme leaves; TEO: Thyme essential oil.

increased the percentages of carcass and breast in Japanese quail, but had no effect on the relative weights of the thighs, drumsticks, spleen, liver, heart, or abdominal fat. These results are in line with earlier research showing that thyme extract powder or essential oil typically has no effect on the weights of the pancreas, spleen, liver, or heart (Hernández *et al*., 2004; Sarica *et al*., 2005). Similarly, Kheiri *et al*. (2018) found that dietary thyme (2 g/kg) had no effect on organ weights or carcass yield in Japanese quail, with yields of breast and leg meat that were similar to those of control and antibiotic-treated birds.

More recently, Maulod *et al*. (2022) reported that the inclusion of 0.5%-1% thyme powder in feed increased the dressing percentage in Japanese quail females (with no changes in males) and that thyme-supplemented quail had better breast, wing, leg, and back proportions than control quail.

Blood Biochemical Parameters

Dietary supplementation with thyme, provided as leaf powder, aqueous extract, or essential oil, has been consistently associated with modifications in blood biochemical and hematological parameters in poultry, reflecting improvements in metabolic status, liver and kidney function, immune competence, and lipid metabolism (Table 3).

Deeb *et al.* (2024) reported that TLP (1-3 g/kg diet) induced linear responses in serum total protein, albumin, the albumin/globulin (A/G) ratio, alanine aminotransferases (ALT), and creatinine levels in broiler chickens. Notably, creatinine concentrations were significantly lower in birds fed 2 or 3 g/kg TLP compared with the control and 1 g/kg groups, suggesting improved renal function. In contrast, serum globulin and aspartate aminotransferase (AST) levels were not affected by TLP supplementation. Similarly,

Table 3. Previous research underscores the effect of thyme supplementation on blood biochemical parameters in poultry

Study	Species (age)	Thyme form[1]	Dose	Key outcomes[2]
Deeb *et al.* (2024)	Broilers, Ross 308 (1-38 d)	TLP	1-3 g/kg diet	Increased total protein, albumin, globulin, and A/G ratio; reduced creatinine, indicating improved renal function; ALT activity increased but was within physiological range.
El-Hadad *et al*. (2024)	Male Gimmizah chickens	TLAE	4 mL/10 L water	Increased glucose, hemoglobin, hematocrit, and T_3; elevated IgG, IgM, and total antioxidant capacity; reduced oxidative stress markers.
Eidrisha *et al*. (2022)	Japanese quail (1-42 d)	TP	5, 10 g/kg diet	No significant effects of thyme on protein fractions or lipid ratios
Maulod *et al*. (2022)	Japanese quail (1-42 d)	TP	0.5%, 0.75%, 1 %	Decreased cholesterol, triglycerides, and LDL; increased HDL concentrations
Nameghi *et al*. (2022)	Broilers, Ross 308 (14-42 d)	TP	0.38%	Reduced triglycerides, total cholesterol, and LDL, confirming hypocholesterolemic effects.
Adam *et al.* (2020)	Broilers, Arbor Acres (1–35 d)	TP/TEO	2.5-5 g/kg	Increased HDL (highest at 200 mg/kg thyme oil); reduced VLDL; elevated WBC, lymphocytes, and heterophils, indicating enhanced immune competence.
Aldik *et al*. (2020)	Broilers, Ross 308 (1-42 d)	TLP	2, 4, 6 g/kg diet	Significant reduction in LDL-cholesterol, suggesting hypolipidemic activity.
Hesabi Nameghi *et al.* (2019)	Broilers, Ross 308 (1-42 d)	EO blend (thyme–peppermint–eucalyptus)	150 ppm water	Reduced ALT, AST, and ALP activities; decreased cholesterol levels, reflecting improved liver function.
Khafar *et al*. (2019)	Broilers, Ross 308 (1-42 d)	TEO	150, 200 mg/kg	Reduced AST activity under heat stress conditions, indicating hepatoprotective effects.
Kheiri *et al*. (2018)	Japanese quails (7-35 d)	TP	2 g/kg diet	Minimal effects on AST and ALT; increased HDL; no significant changes in total protein or albumin.
Abdel-Ghaney *et al*. (2017)	Broilers, Cobb (1-35 d)	TLP	0.5%, 1.0%, 1.5% diet	Increased globulin levels; significant reductions in serum cholesterol and triglycerides at weeks 3 and 5.
Khaksar *et al*. (2012)	Japanese quail (1-35 d)	TEO	1 g/kg diet	Reduced serum glucose, triglycerides, and cholesterol, indicating improved metabolic health.

Note: [1]TLP: Thyme leaf powder; TP: Thyme powder; TEO: Thyme essential oil; TLAE: Thyme leaf aqueous extract. [2]A/G, albumin/globulin ratio; ALT, alanine aminotransferase; AST, aspartate aminotransferase; ALP, alkaline phosphatase; TC, total cholesterol; TG, triglycerides; HDL, high-density lipoprotein; LDL, low-density lipoprotein; VLDL, very-low-density lipoprotein; WBC, white blood cells; T_3, triiodothyronine; IgG, immunoglobulin G; IgM, immunoglobulin M; TAC, total antioxidant capacity.

Abdel-Ghaney *et al.* (2017) observed increased serum total protein and globulin concentrations in broilers supplemented with thyme at 5 or 15 g/kg during the later stages of growth, whereas albumin, creatinine, and ALT levels remained unchanged. These findings suggest that thyme may enhance protein metabolism without exerting adverse effects on liver or kidney function.

Several studies have demonstrated that thyme supplementation positively modulates hematological/ biochemical indices associated with immune competence (El-Ghousein & Al-Beitawi, 2009; Khatun *et al.,* 2025; Yasin *et al.,* 2025). In addition, thyme supplementation in broiler diets (powder or oil) has a substantial beneficial effect on hematological responses, as the bioactive phenols (thymol and carvacrol) exert a protective effect on red blood cell membranes by neutralizing free radicals, which reduces oxidative hemolysis and maintains higher hemoglobin levels and packed cell volume. Furthermore, thyme acts as an immunomodulator, often leading to a more favorable white blood cell profile. By lowering systemic inflammation and protecting hematopoietic tissues, thyme ensures a more robust circulatory system capable of efficient oxygen transport and superior immune defense. Total white blood cells (WBC), lymphocyte, and heterophil counts were elevated in birds fed 2.5 or 5 g of thyme powder/kg diet and those receiving 100 or 200 mg thyme oil/kg diet (Adam *et al.,* 2020). The heterophil: lymphocyte ratio was similarly beneficial, indicating that there was an improvement in the immune competence of the broilers and decreased physiological stress. Adam *et al*. (2020) reported increased total white blood cell counts, lymphocyte percentages, and heterophil numbers in broilers fed thyme powder (2.5-5 g/kg) or thyme oil (100-200 mg/kg). The heterophil-to-lymphocyte ratio was favorably reduced, indicating lower physiological stress and enhanced immune responsiveness. Consistent immunostimulatory effects were also reported by Hassan and Awad (2017), who observed increased white blood cell and lymphocyte counts in broilers fed 2 or 5 g/kg thyme, supporting the role of thyme as a natural immune-modulating feed additive.

Recent studies show that thyme supplementation has positive effects on lipid metabolism. Adam *et al*. (2020) indicated that thyme powder/oil decreases serum triglycerides, total cholesterol, and very-low-density lipoprotein (VLDL) with concomitant increases in levels of high-density lipoprotein (HDL), especially in the case of broiler chickens that were provided with 200 mg/kg thyme oil. Aldik *et al*. (2020) researched the hypolipidemic effects of thyme and reported that the supplementation of 4-6 g/kg thyme powder to broilers increased HDL and globulin concentrations and decreased serum glucose, total cholesterol, triglycerides, and low-density lipoprotein (LDL). Comparable improvements in lipid profiles were reported in broilers receiving thyme–peppermint–eucalyptus essential oil blends (Hesabi Nameghi *et al.,* 2019) and in birds fed a combination of thyme and rosemary powders (Nameghi *et al.,* 2022), further supporting the lipid-lowering potential of thyme-based phytogenic additives.

The bioactive phenolic monoterpenes thymol and carvacrol are the primary mediators of the physiological activities of *Thymus vulgaris* on the hematological and biochemical profiles of birds. By inhibiting the activity of the rate-limiting enzyme β-hydroxy-β-methylglutaryl-coenzyme A (HMG-CoA) reductase in the hepatic biosynthesis of cholesterol, and concomitantly enhancing the activity of lipoprotein lipase (LPL) to facilitate the hydrolysis of triglycerides and VLDL, thymol and carvacrol produce a hypolipidemic effect. Thyme also possesses immunomodulatory activity, enhancing the proliferation of lymphocytes and the serum globulin levels, indicating an improved humoral immunity. The high antioxidant activity of the flavonoids in thyme reduces lipid peroxidation, stabilising the cell membranes and ensuring the maximum efficiency of the liver's metabolic activities, as evidenced by the decrease in serum glucose levels, indicating improved insulin sensitivity and glucose metabolism (Nagoor Meeran *et al*., 2017; Saied *et al*., 2025).

Furthermore, thyme supplementation has been demonstrated to alleviate metabolic and oxidative disturbances under conditions of heat stress. Khafar *et al*. (2019) found that TEO (150–200 mg/kg diet) restored levels of corticosterone, malondialdehyde, triglycerides, and cholesterol to normal in heat-stressed broilers. This shows that the antioxidant capacity and metabolic stability of the birds improved. Attia *et al*. (2017) also found that broilers given thyme oil (1.5–2.0 g/kg) had higher levels of total protein and globulin in their blood and lower levels of AST activity. This shows that thyme oil protects the liver and boosts the immune system. El-Hadad *et al*. (2024) found that adding TLAE (4 ml/10 L drinking water) to Gimmizah chickens' diets raised their hemoglobin, hematocrit, glucose, creatinine, and cholesterol levels while lowering their AST, ALT, and malondialdehyde levels.

In Japanese quail, responses to thyme supplementation appear more variable. Triglycerides and serum protein fractions were not significantly affected by thyme powder, according to Eidrisha *et al*. (2022). On the other hand, Khaksar *et al*. (2012) and Maulod *et al*. (2022) showed that quail supplemented with thyme essential oil or powder had significantly lower serum triglycerides, total cholesterol, LDL, and glucose levels, along with higher HDL concentrations. In a similar vein, Kheiri *et al*. (2018) found that supplementing with thyme raised HDL levels but had little effect on total cholesterol and protein metabolism. Thymol and carvacrol, two of thyme's bioactive phenolic compounds, are mainly responsible for its hypolipidemic effects. According to Lee *et al*. (2003a, b), these substances have been demonstrated to inhibit hepatic 3-hydroxy-3-methylglutaryl coenzyme A (HMG-CoA) reductase, a crucial enzyme involved in the biosynthesis of cholesterol.

Recent evidence from Saied *et al*. (2025) indicates that thyme oil supplementation effectively modulates lipid profiles, leading to a reduction in serum cholesterol. Likewise, a recent meta-analysis by Hassanpour *et al*. (2025) demonstrated that thyme-based additives consistently exert hypocholesterolemic effects across various poultry trials. Nevertheless, the magnitude of these responses may vary across breeds, sexes, ages, environmental conditions, and the synergistic effects of other dietary ingredients.

Immune and Antioxidant Responses to Thyme Supplementation

Dietary supplementation with thyme has been widely reported to enhance both immune competence and antioxidant defenses in poultry, largely due to the presence of phenolic compounds such as thymol and carvacrol. A synthesis of the main immunological and antioxidant responses observed in different poultry species and experimental conditions is provided in Table 4. According to Deeb *et al.* (2024), serum immunoglobulin Y (IgY) and IgM concentrations were higher in broiler chickens fed TLP (1-3 g/kg diet) than in the control group, indicating a significant improvement in humoral immunity. The highest IgM levels were observed in birds fed a 2 g TLP/kg, indicating that moderate supplementation levels may be optimal for stimulating antibody-mediated immune responses.

Consistent findings were reported by Abdel-Ghaney *et al.* (2017), who observed significant increases in serum IgG, IgM, interferon-gamma (IFN-γ), and interleukin-10 (IL-10) concentrations in broilers fed diets supplemented with 5, 10, or 15 g/kg thyme. These results suggest that thyme supplementation enhances both humoral and cell-mediated immunity. Similarly, Hassan and Awad (2017) reported elevated IgG levels and increased nitric oxide (NO) production in broilers fed 5 g/kg thyme, reflecting stimulation of both adaptive and innate immune responses. Enhanced immune organ development and antibody titers against infectious bursal disease (IBD) were also observed in broilers receiving thyme oil supplementation (0.3 mL/L drinking water), along with increased relative weights of the bursa of Fabricius, thymus, and spleen (Almremdhy & Al-Khafaji 2020).

Table 4. Effects of thyme supplementation on immunity and antioxidant parameters in poultry

Study	Species (age)	Thyme form[1]	Dose	Key outcomes[2]
Deeb *et al*. (2024)	Broilers, Ross 308 (1-38 d)	TLP	1-3 g/kg diet	↑ IgY (all TLP groups); ↑ IgM (max at 2 g/kg); ↑ SOD and ↓ MDA (optimal at 1 g/kg), indicating enhanced humoral immunity and antioxidant capacity at moderate doses.
El-Hadad *et al*. (2024)	Gimmizah chickens	TLAE	4 mL/10 L water	↑ IgG and IgM, improved hematological indices, ↑ total antioxidant capacity (TAC) and ↓ MDA, indicating enhanced immunity and antioxidant defense.
Nameghi *et al*. (2022)	Broilers, Ross 308 (14-42 d)	TP	0,38%	↓ MDA levels, indicating improved antioxidant status and reduced lipid peroxidation.
Aldik *et al*. (2020)	Broilers, Ross 308 (1-42 d)	TLP	2, 4, 6 g/kg diet	↑ Globulin and ↑ albumin/globulin ratio, suggesting improved immune-related protein synthesis and immune competence.
Almremdhy and Al-Khafaji (2020)	Broilers, Ross 308 (1-35 d)	TO	0.3 mL/L water	↑ Antibody titers against IBD and ↑ relative weights of bursa, thymus, and spleen, indicating enhanced humoral immunity and immune organ development.
Hesabi Nameghi *et al*. (2019)	Broilers, Ross 308 (1-42 d)	EO blend (thyme–peppermint–eucalyptus)	150 ppm water	Dose-dependent ↑ antibody titers against ND, IB, and IBD, indicating enhanced humoral immune response.
Talazadeh and Mayahi (2017)	Broilers, Ross 308 (1-35 d)	TLAE	0.1%, 0.15%, 0.2 % in water	↑ Antibody response to influenza vaccination, reflecting improved vaccine-induced humoral immunity.
Attia *et al*. (2017)	Broilers, Arbor Acres (1-28 d)	TO	1.0–2.0 g/kg	↑ WBC counts and ↑ antibody titers against IBD, indicating enhanced general and adaptive immune responses.
Hassan and Awad (2017)	Broilers, Cobb 500 (1-42 d)	TLP	2, 5, 8 g/kg diet	↑ IgG and ↑ nitric oxide (NO), reflecting stimulation of humoral and innate immune pathways.
Abdel-Ghaney *et al*. (2017)	Broilers, Cobb (1-35 d)	TLP	0.5%, 1.0%, 1.5% diet	↑ IgG, IgM, IFN-γ, IL-10; ↑ GSH, SOD, and GST; ↓ MDA, demonstrating strengthened humoral and cell-mediated immunity with reduced oxidative stress.

Note: [1]TLP: Thyme leaf powder; TP: Thyme powder; TEO: Thyme essential oil; TO: Thyme oil; TLAE: Thyme leaf aqueous extract. ↑ = increased; ↓ = decreased. [2]IgY, immunoglobulin Y; IgG, immunoglobulin G; IgM, immunoglobulin M; IFN-γ, interferon gamma; IL-10, interleukin 10; NO, nitric oxide; WBC, white blood cells; IBD, infectious bursal disease; ND, Newcastle disease; IB, infectious bronchitis; SOD, superoxide dismutase; MDA, malondialdehyde; GSH, glutathione; GST, glutathione S-transferase; TAC, total antioxidant capacity.

Thyme supplementation has also been associated with improved vaccine-induced immune responses. Talazadeh and Mayahi (2017) reported enhanced antibody titers following influenza vaccination in birds receiving thyme extract, whereas Attia *et al.* (2017) observed increased white blood cell counts and elevated antibody titers against IBD in broilers supplemented with thyme oil (1.0-2.0 g/kg) or mannanoligosaccharides. However, inconsistent findings have been reported in some studies, as Teymouri Zadeh *et al.* (2009) and Rahimi *et al.* (2011) did not observe significant improvements in antibody responses following thyme supplementation. These discrepancies may be attributed to differences in thyme chemotype, dosage, administration route, vaccination protocols, or bird age. In addition to its immunomodulatory effects, thyme supplementation exerts a pronounced influence on antioxidant status. Deeb *et al.* (2024) reported increased superoxide dismutase (SOD) activity and reduced malondialdehyde (MDA) concentrations in broilers fed TLP, with the most favorable antioxidant profile observed at 1 g/kg supplementation. Similar antioxidant-enhancing effects were reported by Aldik *et al*. (2020), who observed improved globulin concentrations and albumin-to-globulin ratios in broilers supplemented with 4-6 g/kg thyme, reflecting enhanced protein synthesis and antioxidant capacity.

Abdel-Ghaney *et al.* (2017) showed that thyme supplementation dramatically raised muscle antioxidant enzymes, such as glutathione, SOD, and glutathione S-transferase, while lowering MDA levels, indicating less oxidative damage and lipid peroxidation. Similar findings have also been noted by Hesabi Nameghi *et al.* (2019), who observed enhanced humoral immunity and antioxidant status in broilers supplemented with thyme–peppermint–eucalyptus essential oil blends at up to 200 ppm. In Gimmizah chicken, El-Hadad *et al.* (2024) demonstrated that aqueous extract of thyme leaves (4 ml/10 L drinking water) effectively decreased plasma MDA concentration, while triiodothyronine (T_3), IgG, IgM, and total antioxidant capacity were increased. These results show that the aqueous extract of thyme leaves is effective in modulating endocrine, immune, and antioxidant status. The immunomodulatory and antioxidant effects of thyme are largely attributed to its phenolic constituents, which exhibit strong free radical scavenging activity, enhance endogenous antioxidant enzyme systems, and modulate cytokine production. By reducing oxidative stress and supporting immune cell function, thyme supplementation contributes to improved health resilience, particularly under challenging environmental or pathological conditions.

Gut Morphology and Microbial Responses to Thyme Supplementation

One of the main mechanisms by which phytogenic feed additives, such as thyme, have a beneficial impact on broiler performance and health is through their ability to modulate intestinal morphology and microbiota. A brief account of the main findings related to broiler response, including gut morphology and microbiota, following dietary supplementation with thyme is provided in Table 5. Thyme supplementation has been found to modulate broiler microbiota, inhibiting harmful bacteria while increasing beneficial ones. Aldik *et al*. (2020) found that broilers fed diets supplemented with 4-6 g/kg feed of thyme had lower total aerobic bacterial and coliform counts, both in the duodenum and cecum, while showing a high increase in *Lactobacillus* populations. This shows that thyme leaf powder, while being a selective antimicrobial agent, is beneficial to broilers, especially in creating a balanced microbiota, thus helping them utilize nutrients better. Abdel-Wareth *et al*. (2012) found that there

Table 5. Previous studies showing the effect of thyme supplementation on the gut microbiota and morphology in poultry

Study	Species (age)	Thyme form¹	Dose	Key outcomes²
Nameghi *et al.* (2022)	Broilers, Ross 308 (14-42 d)	TP	0,38%	↑ Ileal villus height and villus height:crypt depth ratio; ↑ beneficial ileal microbiota, supporting enhanced nutrient absorption and intestinal health.
Aldik *et al.* (2020)	Broilers, Ross 308 (1-42 d)	TLP	2, 4, 6 g/kg diet	↓ Total aerobic bacteria and coliforms; ↑ Lactobacillus populations, indicating antimicrobial activity with preservation of beneficial gut microflora.
Hesabi Nameghi *et al.* (2019)	Broilers, Ross 308 (1-42 d)	EO blend (thyme–peppermint–eucalyptus)	150 ppm water	↑ Ileal villus height and villus height:crypt depth ratio; 150 ppm ↑ Lactobacillus, 200 ppm ↓ *E. coli*, indicating improved gut structure and microbial balance.
Abdel-Wareth *et al.* (2012)	Broilers, Roass 308 (1-42 d)	TP	15, 20 g/kg diet	↓ Lactobacillus spp. with no effect on total bacterial count, suggesting selective microbiota modulation rather than broad-spectrum antimicrobial action.
Khaksar *et al.* (2012)	Japanese quail (1-35 d)	TEO	1 g/kg diet	↑ Lactobacillus and ↓ *E. coli* populations in the ileum are attributed to antimicrobial actions of thymol and carvacrol.

Note: ¹TLP: Thyme leaf powder; TP: Thyme powder; TEO: Thyme essential oil. ↑ = increased; ↓ = decreased. ²VH, villus height; CD, crypt depth; VH:CD, villus height to crypt depth ratio.

was a decline in *Lactobacillus spp*. counts, while total bacterial counts were unaffected, following dietary supplementation with thyme, indicating that thyme might have a selective impact on microbiota rather than being a general antimicrobial agent. Thyme's selective antimicrobial action is primarily dictated by the lipophilic nature of thymol and carvacrol, which preferentially disrupt the phospholipid bilayers of specific bacteria. While many Gram-negative pathogens like *E. coli* and *Salmonella* are highly sensitive to this membrane destabilization, the impact on beneficial Gram-positive bacteria like *Lactobacillus spp*. is often dose-dependent.

Besides this microbial modulation effect, thyme supplementation has also been observed to have a positive effect on intestinal morphological characteristics that are associated with increased absorptive capacity. In this regard, it has been observed by Hesabi Nameghi *et al*. (2019) that thyme-peppermint-eucalyptus essential oil blends at a concentration of 150-200 ppm increased ileal villus height and ileal VH:CD ratio in broilers, indicating improved intestinal integrity and epithelial turnover. Moreover, the higher inclusion level (200 ppm) reduced ileal *Escherichia coli* counts, while 150 ppm increased *Lactobacillus* populations at both 21 and 42 days of age. Similarly, Nameghi *et al.* (2022) demonstrated that dietary inclusion of a blend containing 0.375% thyme and 0.375% rosemary significantly increased ileal villus height and VH:CD ratio, accompanied by an increased abundance of beneficial ileal microbiota. These morphological and microbial adaptations suggest improved digestive efficiency and nutrient absorption in thyme-supplemented birds.

In Japanese quail, Khaksar *et al*. (2012) reported that supplementation with TEO (1 g/kg diet) significantly increased ileal *Lactobacillus* populations and reduced *Escherichia coli* counts, indicating a favorable shift in the intestinal microbial ecosystem. The antimicrobial effects were attributed to the phenolic constituents of thyme oil, particularly thymol and carvacrol, which have been shown to inhibit the growth of *E. coli* and *Salmonella typhimurium* in vitro. However, the results of the same study indicated variable results in the different experimental conditions. The efficacy of thyme essential oil in modulating the intestinal microbial ecosystem may be dependent on the diet formulation, concentration of the essential oil, health status of the flock, and the environment (Khaksar *et al*., 2012).

Overall, the above findings suggest that the supplementation of thyme may improve gut health by exerting its selective antimicrobial properties and improving the morphology of the intestine. This may lead to an improvement in the digestibility of nutrients and the performance of the animal. However, the conflicting findings of the above studies suggest that the inclusion levels and other factors, such as species and environment, should be considered for the application of thyme-based feed additives in poultry.

Regulation of Gene Expression by Thyme Supplementation in Poultry

The effects of thyme supplementation on gene expression in poultry remain underexplored, though recent studies have provided some valuable insights into its potential role in regulating immune and intestinal barrier functions. A summary of the gene expression data related to thyme supplementation is presented in Table 6. Thyme supplementation has been shown to influence the expression of genes involved in the inflammatory response, with significant implications for gut health and overall immunity. In this context, Hassan and Awad (2017) studied the relative expression of mRNAs for some major inflammatory cytokines such as interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-alpha), and IFN-gamma (IFN-γ), as well as nuclear factor kappa-light-chain-enhancer of activated B cells p50 subunit (NF-κB p50), in broilers that received thyme-supplemented diets. The results revealed that dietary thyme supplementation resulted in reduced expression of pro-inflammatory cytokines. TNF-alpha expression was significantly inhibited in broilers that received thyme at doses of 5-8 g/kg. This indicates that thyme supplementation may exert an anti-inflammatory response in broilers. IL-6 expression was significantly reduced in broilers that received thyme at a dose of 8 g/kg. However, IL-6 expression was not significantly reduced in broilers that received thyme at doses of 2 and 5 g/kg. This may indicate that IL-6 is reduced in a dose-dependent manner. Moreover, the study indicated that thyme supplementation does not affect the expression of IFN-γ and NF-κB p50. This may indicate that thyme supplementation targets specific aspects of inflammation. Thyme supplementation also affects mucosal health in broilers. Hassan and Awad (2017) also studied the expression of mucin2 (MUC2), which is a major protein in the mucus layer in the intestines and is essential for maintaining the integrity of the mucus layer. The results revealed that MUC2 expression is significantly induced in broilers that received thyme at a dose of 8 g/kg. A similar but insignificant increase in MUC2 expression was also noted in broilers that received thyme at a dose of 2 g/kg. This may indicate that thyme supplementation may exert beneficial

Table 6. Research showing the effect of thyme supplementation on selected gene expression in poultry

Study	Species (age)	Thyme form	Dose	Key outcomes[2]
Hassan and Awad (2017)	Broilers, Cobb 500 (1-42 d)	TLP[1]	2, 5, 8 g/kg diet	↓ TNF-α expression at 5 and 8 g/kg; ↓ IL-6 at 8 g/kg; no significant effect on IFN-γ or NF-κB p50; ↑ Mucin2 expression at 5 and 8 g/kg, indicating attenuation of inflammatory signaling and enhancement of intestinal barrier integrity.

Note: [1]TLP: Thyme leaf powder. ↑ = increased; ↓ = decreased. [2]IL-6, interleukin 6; TNF-α, tumor necrosis factor alpha; IFN-γ, interferon gamma; NF-κB p50, nuclear factor kappa-light-chain-enhancer of activated B cells p50 subunit.

effects in maintaining the integrity of the mucus layer in the intestines. This may be beneficial for improved gut health in broilers. The modulation of inflammation and mucin2 may be important for understanding the beneficial role of thyme supplementation in improving gut health in broilers. Improved gut health may be essential for improved growth performance in broilers. Moreover, thyme extracts reduce the expression and activity of the COX-2 enzyme. This results in lower production of prostaglandins (specifically $PG\ E_2$), which are responsible for pain, fever, and vasodilation in birds. Thyme also targets the LOX pathway, reducing the synthesis of leukotrienes. These molecules are potent inflammatory mediators that can cause airway constriction and attract immune cells (chemotaxis) that, if overactive, damage gut tissue (Zaazaa *et al*., 2022; Basiouni *et al*., 2023). However, given the relatively small number of studies on gene expression in response to thyme supplementation, further research is needed to fully elucidate the broader molecular mechanisms at play. Studies exploring the effects of thyme on other key genes involved in immunity, metabolism, and digestion will provide a more comprehensive understanding of its potential benefits for poultry production.

CONCLUSION

Based on the available scientific literature, it has been established that thyme is a promising phytogenic compound that could be effectively used as a feed additive for broilers, layers, and quail. In broiler chickens, supplementation of thyme powder and essential oil has shown positive results for growth performance, efficiency, and carcass characteristics. The results were optimal when thyme powder was used at levels of 0.5%-2%, and essential oil was used at levels of 100-200 mg/kg. In laying hens, aqueous leaf extract of thyme (4 mL/10 L of drinking water) has shown positive results for enhancing reproductive performance, egg quality, and antioxidant status. In addition, thyme has shown positive results for modulating immune system functions (IgG, IgM), and lipid metabolism. In feed formulation, the use of powder at 1% provides a cost-effective strategy for enhancing gut health and reducing pathogen load (*E. coli*), particularly in tropical regions where heat-induced oxidative stress is prevalent. Ultimately, applying thyme-based supplementation offers a sustainable pathway for the industry to maintain high productivity while meeting increasing consumer demand for antibiotic-free poultry products.

FUTURE RECOMMENDATIONS

Optimal Dose and Formulation: Further studies should determine species-specific optimal inclusion rates of thyme and evaluate the comparative effectiveness of its different forms (leaves, powder, and essential oils) across various poultry species and other livestock.

Mechanistic Insights: Molecular and omics-based approaches are recommended to elucidate the mechanisms of bioactive compounds in thyme, particularly regarding immune modulation, antioxidant pathways, and gut microbiota composition.

Stress Mitigation: Investigate the potential of thyme supplementation to mitigate the adverse effects of heat stress and other environmental challenges, especially in tropical poultry production systems.

Long-Term Production Effects: Assess the long-term impact of dietary thyme on egg quality, reproductive performance, growth efficiency, and meat shelf-life under commercial conditions.

Economic Analysis: Conduct comprehensive cost analyses to evaluate the feasibility and profitability of incorporating thyme into routine feeding programs in both small- and large-scale tropical poultry farms.

CONFLICTS OF INTEREST

K. El-Sabrout serves as an editor of the Tropical Animal Science Journal but has no role in the decision to publish this article. The authors declare that there are no known conflicts of interest associated with this publication.

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DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work, the author(s), in some sentences, used Google Gemini, Grammarly, and ChatGPT in order to improve the readability and language of the manuscript, as well as create an illustrative image. After using this tool/service, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the publication.

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