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Oregano Essential Oil in Broiler Nutrition: A Natural Alternative to Antibiotics

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Abstract

The poultry industry faces increasing pressure to reduce reliance on antibiotic growth promoters (AGPs) due to rising antimicrobial resistance and consumer demand for safer products. Oregano essential oil (OEO), a plant-derived bioactive compound rich in carvacrol and thymol, has emerged as a promising natural alternative. This review consolidates recent findings on the effects of OEO supplementation in broiler diets, focusing on growth performance, carcass traits, immunity, antioxidant activity, antimicrobial potential and economic outcomes. Dietary inclusion of OEO (300–600 mg/kg feed) has been reported to enhance feed intake (4–8%), body weight (4–10%) and feed conversion ratio (4–9%), while modulating gut microflora, improving nutrient absorption and reducing pathogenic bacterial populations. OEO also exerts significant antioxidant and anti-inflammatory effects, including increased superoxide dismutase and glutathione peroxidase activity, reduced malondialdehyde levels and improved humoral immunity (IgG). Carcass quality, including dressing percentage and muscle yield, is positively influenced and economic analyses indicate improved total return, relative economic efficiency and feed cost efficiency. The evidence highlights OEO as a multifaceted natural growth promoter that can improve poultry productivity, health and profitability, representing a sustainable strategy for modern broiler production.

Keywords: Oregano essential oil, broiler production, growth promoter, antimicrobial activity, antioxidant activity, carcass traits, economic efficiency, poultry nutrition, carvacrol, thymol

INTRODUCTION

The poultry industry in India is one of the fastest-growing sub-sectors of agriculture, playing a vital role in enhancing food security, generating employment and supporting economic growth. In the fiscal year 2023-24, India's total meat production reached 10.25 million tonnes, placing the country fifth globally, behind China, the USA, Brazil and Russia. This represented a year-over-year growth of 4.95% (DADH, 2023-24). Among various species, poultry made the most significant contribution, accounting for 48.96% of the total

meat production. In 2024, the Indian poultry market was valued at ₹2,30,400 crore. The poultry industry contributes approximately 1% to India's National GDP and 14% to the Livestock GDP, highlighting its importance in the agricultural economy. On a global scale, the total poultry population stands at 33 billion, with India accounting for 851.81 million of that figure. Globally, poultry meat production is estimated at 137 million tonnes, while India contributes 5 million tonnes to this total (FAOSTAT, 2024; BAHS, 2024).

The poultry industry plays a vital role in meeting the growing demand for animal protein, with broiler production expanding rapidly to keep pace with rising meat consumption. To enhance growth performance and maintain flock health, poultry farmers have traditionally relied on Antibiotic Growth Promoters (AGPs). These substances have been widely used to improve feed efficiency, support gut health and prevent disease outbreaks (Dibner & Richards, 2005). However, the long-term and widespread use of AGPs has led to serious global concerns, including the development of antibiotic-resistant bacteria and the presence of drug residues in meat products. As antimicrobial resistance emerges as a significant threat to public health, countries around the world have begun to respond. The European Union banned the use of AGPs in poultry production in 2006 (Barug *et al.,* 2006) and China followed with a similar ban in 2020. These developments have prompted a growing need for natural, safe and sustainable alternatives to antibiotics in poultry feed. In this context, plant-based additives and other natural compounds with antimicrobial, antioxidant and growth-promoting properties are gaining increasing attention as effective replacements for conventional AGPs.

Essential oils (EOs) are natural mixtures of fragrant and volatile compounds derived from aromatic plants, often named based on the plant's origin and scent characteristics. The term "essential" was first introduced by Paracelsus in his theory of "*quinta essentia*" referring to a concentrated essence believed to possess powerful medicinal properties (Oyen and Dung, 1999). In recent years, essential oils have gained significant attention in poultry production for their potential to enhance growth, improve health and serve as natural alternatives to synthetic additives and antibiotics. Their antimicrobial, antioxidant and digestive-stimulating properties make them promising candidates as natural growth promoters. Among the various essential oils used in poultry farming, oregano oil, thyme oil, cinnamon oil, ginger oil and eucalyptus oil are particularly popular due to their proven efficacy in promoting productivity and maintaining flock health (El-Hack *et al.,* 2022).

Oregano essential oil (Oregano essential oil) is derived from the oregano plant, an herb that has been cultivated for centuries, particularly in the Mediterranean region and is now

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widely found across many continents. The name "oregano" roughly translates to "mountain joy," reflecting its historical association with happiness and well-being in ancient Greek and Roman cultures (Singletary, 2010). Oregano oil is primarily extracted from species within the *Origanum* genus, notably *Origanum vulgare* and *Origanum majorana*, which are known for their high content of bioactive compounds. These compounds are responsible for the oil's potent antimicrobial and growth-enhancing properties. Oregano essential oil has demonstrated a wide range of beneficial effects in poultry production, including antimicrobial, antioxidant, anti-inflammatory and antiviral activities, making it a promising natural alternative to conventional antibiotics (Leyva-López *et al.,* 2017).

COMPOSITION OF OREGANO ESSENTIAL OIL:

The major bioactive components of oregano oil include 60–80% carvacrol, a potent antimicrobial and antioxidant; 5–10% thymol, known for its strong antifungal and antibacterial properties; and 10–15% of compounds like terpinenes, p-cymene and rosmarinic acid, which contribute to immune modulation and support gut health (Puvaca *et al.,* 2022).

Carvacrol and thymol are structurally related monoterpenoid phenols sharing the same molecular formula ($C_{10}H_{14}O$), with differences arising from the positional arrangement of the methyl and isopropyl groups on the aromatic ring. Carvacrol (5-isopropyl-2-methyl phenol) is predominantly present in oregano (*Lamiaceae*) and is characterized as a colourless to pale yellow liquid with a thymol-like odour, a boiling point of approximately 237 °C, a density of 0.976 g/ml and good chemical stability. In contrast, thymol (5-methyl-2-isopropyl phenol), mainly derived from thyme (*Lamiaceae*), occurs as white crystalline solids, possesses a pungent and caustic taste and exhibits a slightly lower boiling point (233 °C) and density (0.969 g/ml), while maintaining comparable stability. Both compounds demonstrate pronounced biological activities, notably antimicrobial, anti-inflammatory and antioxidant effects, which underpin their extensive application as natural flavouring agents and functional bioactive components in food, pharmaceutical and animal nutrition research.

EXTRCTION OF OREGANO ESSENTIAL OIL:

Hydrodistillation is one of the oldest and simplest methods for extracting essential oils, first developed by the Persian scientist Avicenna, who also introduced the use of the alembic in the distillation process. The rose was the first plant to be extracted and purified using this technique. In hydrodistillation, plant materials are immersed directly in water within a vessel known as an alembic and the entire mixture is brought to a boil. The setup typically includes a heat source, the alembic, a condenser to cool and convert the vapor into liquid and a decanter

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to collect the resulting condensate and separate the essential oil from the water (Rassem *et al.,* 2016).

This method is still widely used today due to its simplicity and effectiveness. The yield of essential oils from individual plants or their parts typically ranges from 0.2% to 2.0%, depending on the plant species and conditions of extraction.

Oregano essential oil serves multiple functions in poultry production, including improving growth performance, enhancing gut morphology, exhibiting strong antimicrobial and antioxidant activities, modulating the immune system and providing an effective anticoccidial effect (El-Hack *et al.,* 2022)."

FUNCTION OF OREGANO ESSENTIAL OIL

Oregano essential oil exerts multiple beneficial functions in poultry production, making it a valuable natural feed additive. It is well recognized for its ability to improve growth performance by enhancing feed efficiency and supporting better nutrient utilization. The strong antimicrobial activity of oregano essential oil helps in suppressing pathogenic microorganisms in the gastrointestinal tract, thereby maintaining a healthier gut microflora. It also plays a significant role in enhancing gut morphology by improving villus height and intestinal integrity, which contributes to improved digestion and absorption of nutrients. In addition, oregano essential oil exhibits potent antioxidant activity, protecting tissues from oxidative stress and supporting overall metabolic health. It modulates the immune system by enhancing both humoral and cellular immune responses, thereby improving disease resistance. Furthermore, oregano essential oil shows notable anticoccidial effects, reducing the severity and impact of coccidial infections and supporting intestinal health in poultry.

EFFECTS OF OREGANO ESSENTIAL OIL

Anti- Microbial activity of Oregano essential oil:

The antimicrobial activity of Oregano essential oil (Oregano essential oil) against Staphylococcus aureus, particularly methicillin-resistant S. aureus (MRSA), involves multiple mechanisms. Firstly, Oregano essential oil disrupts the integrity of the bacterial cell membrane, causing irreversible damage that results in the leakage of essential cellular contents such as ions (Na^+, K^+), proteins and enzymes. This leads to increased electrical conductivity, a 37.39% reduction in protein concentration and a 17.71% decrease in alkaline phosphatase (AKP) activity, ultimately impairing normal cellular functions. Additionally, Oregano essential oil inhibits cellular metabolism by suppressing oxidoreductase activity, as shown by

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a 93.31% loss in metabolic activity at twice the minimum inhibitory concentration (MIC), measured via the resazurin assay (lambert *et al.,* 2001).

Moreover, Oregano essential oil interferes with the tricarboxylic acid (TCA) cycle by inhibiting key enzymes such as citrate synthase, isocitrate dehydrogenase and α-ketoglutarate dehydrogenase. This disruption leads to a buildup of citric acid and a decline in other intermediates like fumaric, succinic and malic acids, further impairing bacterial energy metabolism (Gaupp *et al.,* 2010). Oregano essential oil also reduces ATP content by 44.32% and significantly inhibits ATPase activity including Na^{+}/K^{+}-, Ca^{2+} and Mg^{2+}-ATPases leading to energy depletion and reduced bacterial viability. In addition, Oregano essential oil damages bacterial genetic material by causing DNA leakage and a 42.87% drop in intracellular DNA content. Its active component, carvacrol, binds to DNA, altering its structure and interfering with replication, transcription and protein synthesis (Wang *et al.,* 2014). Lastly, Oregano essential oil inhibits the expression of the pvl gene, which encodes the virulence factor Panton-Valentine leukocidin, thereby reducing toxin production and the overall pathogenicity of MRSA (Lari *et al.,* 2011).

Cetin *et al.* (2022) reported that supplementation of broiler diets with oregano and rosemary essential oils, alone or in combination, significantly reduced coliforms and Clostridia counts and increased Lactobacilli counts compared to control, with the combination of 200 mg/kg each (OR2) showing the most pronounced effect ($P<0.05$). Roofchaee *et al.* (2024) reported that supplementation of broiler diets with Oregano essential oil at 1200 mg/kg significantly decreased Escherichia coli counts by 2.32% *compared to control, while lactic acid bacteria counts were not significantly affected ($P>0.05$). Supplementation of broiler diets with Oregano, alone or in combination with rosemary essential oil, effectively modulates gut microflora by reducing pathogenic bacteria such as coliforms, Clostridia and E. coli, while promoting beneficial Lactobacilli populations, highlighting its potential as a natural gut health enhancer in poultry.

Anti- Inflammatory activity of Oregano essential oil:

The anti-inflammatory activity of Oregano essential oil is mediated through several interconnected mechanisms, primarily driven by its active compounds, carvacrol and thymol. Oregano essential oil significantly inhibits the production of key proinflammatory cytokines, including tumour necrosis factor-α (TNF-α), interleukins (IL-1β and IL-6) and interferon-γ (IFN-γ), thereby dampening the inflammatory response (Arranz *et al.,* 2015). Additionally, Oregano essential oil downregulates the expression of critical inflammatory biomarkers such as monocyte chemotactic protein-1 (MCP-1), intercellular adhesion molecule-1 (ICAM-1)

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and vascular cell adhesion molecule-1 (VCAM-1), all of which are involved in recruiting immune cells to sites of inflammation. It also reduces the levels of Prostaglandin E2 (PGE2), a key mediator in the initiation and progression of inflammation (Han & Parker, 2017).

Moreover, Oregano essential oil plays a role in suppressing oxidative stress by decreasing the production of reactive oxygen species (ROS) and nitric oxide (NO), which helps protect tissues from oxidative damage and further inflammatory responses (Kumar *et al.,* 2017). Importantly, Oregano essential oil also enhances the body's anti-inflammatory defenses by upregulating interleukin-10 (IL-10), an anti-inflammatory cytokine that helps balance immune activity and prevent excessive tissue injury (Lima *et al.,* 2013). Collectively, these actions highlight Oregano essential oil's potential as a natural anti-inflammatory agent in managing inflammatory conditions.

Ruan *et al.* (2021) reported that supplementation of broiler diets with 300 mg/kg Oregano essential oil significantly increased IgG levels by 31.6% and decreased TGF-β by 45.5% compared to control, while IgM and TNF-α were not significantly affected, indicating enhanced humoral immunity. Supplementation of broiler diets with 300 mg/kg Oregano essential oil enhances humoral immunity, as evidenced by a significant increase in IgG levels and reduction in TGF-β, while IgM and TNF-α remain unaffected, indicating targeted immunomodulatory effects.

Anti- oxidative activity of Oregano essential oil:

The antioxidant activity of Oregano essential oil in poultry nutrition is primarily attributed to its high content of phenolic compounds, particularly carvacrol and thymol. These bioactive components exert potent free radical scavenging effects by donating hydrogen atoms from their hydroxyl (-OH) groups to neutralize harmful radicals like peroxyl (ROO•) and hydroxyl (•OH), effectively interrupting lipid peroxidation chain reactions (Farag *et al.,* 1989). Additionally, Oregano essential oil compounds can chelate pro-oxidant metal ions such as iron (Fe^{2+}) and copper (Cu^{2+}), thereby preventing metal-catalyzed oxidative reactions, such as the Fenton reaction, which accelerate lipid degradation in tissues and feed (Yanishlieva & Marinova, 2001).

Oregano essential oil also inhibits lipid peroxidation by stabilizing polyunsaturated fatty acids (PUFAs) and reducing the formation of malondialdehyde (MDA), a key indicator of oxidative damage (Yanishlieva *et al.,* 1999). Moreover, it enhances the animal's endogenous antioxidant defense system by boosting the activity of key enzymes, including superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPx). Supplementation with Oregano essential oilhas also been shown to help maintain higher levels

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of tissue tocopherol (vitamin E) and PUFAs, further strengthening oxidative resistance (Botsoglou *et al.,* 2003).

Importantly, Oregano essential oil integrates into tissue lipids when included in poultry diets, allowing it to act in situ to delay oxidative deterioration during refrigerated storage. Its antioxidant effects have been found to be comparable to synthetic antioxidants like tocopheryl acetate. Beyond molecular mechanisms, Oregano essential oil positively influences meat quality by preserving colour, flavour, odour and extending shelf life, making it an effective natural preservative in poultry production systems.

Elbaz *et al.* (2025) reported that supplementation of broiler diets with 300 mg/kg Oregano essential oil combined with probiotics (POE) significantly reduced malondialdehyde (MDA) by 51% and increased superoxide dismutase (SOD) activity by 17.2% compared to the positive control (PCO), while no significant effect was observed on total antioxidative capacity (TAC) among treatments. Zhang *et al.* (2022) reported that supplementation of broiler diets with 200 mg/kg natural or synthetic Oregano essential oil significantly increased antioxidant activity, including glutathione peroxidase (10.2% natural, 8.07% synthetic), superoxide dismutase (7.01% natural, 7.37% synthetic) and total antioxidative capacity (12.5% natural, 15.6% synthetic) compared to control, while malondialdehyde levels were not significantly affected, indicating that both natural and synthetic OEO at 200 mg/kg perform similarly in enhancing antioxidative status. Ruan *et al.* (2021) reported that supplementation of broiler diets with Oregano essential oil at 300 mg/kg significantly increased glutathione peroxidase activity by 5.55% compared to control, while total superoxide dismutase, total antioxidative capacity and malondialdehyde levels were not significantly affected. Collectively, supplementation of broiler diets with oregano essential oil, particularly at 200–300 mg/kg and in combination with probiotics, significantly enhanced antioxidant enzyme activities (SOD, GPx), reduced malondialdehyde levels by up to 51% and contributed to improved oxidative stability, demonstrating its effectiveness in strengthening the antioxidative status of poultry.

Growth Promoting activity of Oregano essential oil

The growth-promoting effects of Oregano essential oil in poultry are mediated through several complementary mechanisms that enhance gut health, nutrient utilization and overall physiological efficiency. One of the primary actions of Oregano essential oil is the stabilization of gut microflora, where it suppresses pathogenic bacteria such as E. coli and Clostridium perfringens while promoting beneficial microbial populations. This microbial balance is particularly crucial during early development stages, ensuring a more stable and

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efficient digestive system (Jamroz *et al.,* 2006). Oregano essential oil also stimulates the secretion of digestive fluids and enzymes, including saliva, bile, mucus, amylase and trypsin, which enhances the digestion and absorption of key nutrients like glucose and proteins. Improved gastric retention time further facilitates nutrient extraction from feed (Platel *et al.,* 2004).

Additionally, Oregano essential oil promotes mucus production in the gastrointestinal tract, forming a protective barrier that reduces pathogen adherence to the gut lining and supports intestinal integrity. This protective effect helps minimize the immune system's workload, allowing more energy to be allocated to growth rather than immune defense (Lee *et al.,* 2003). Oregano essential oil also reduces harmful microbial metabolites such as ammonia and biogenic amines, decreasing metabolic stress and improving the internal nutrient environment. Another beneficial mechanism involves mild epithelial irritation caused by essential oils, which can stimulate reflexive secretions and enhance gut motility and function. Collectively, these actions make Oregano essential oil a potent natural growth promoter in poultry production (Franz *et al.,* 2010).

Peng *et al.* (2016) demonstrated that dietary supplementation of oregano essential oil in broiler diets positively influenced growth performance. Supplementation at 600 mg/kg feed significantly ($P < 0.05$) increased average daily feed intake by 8.17% compared to the control, while the 300 mg/kg level showed no significant effect. Final body weight was significantly ($P < 0.05$) improved at both inclusion levels, with increases of 7.68% at 300 mg/kg and 9.65% at 600 mg/kg feed. However, feed conversion ratio was not significantly ($P > 0.05$) affected by oregano essential oil supplementation at either level when compared with the control and avilamycin-supplemented groups. Eler *et al.* (2019) reported that oregano essential oil supplementation at 300 mg/kg significantly ($P < 0.05$) increased total feed intake, while higher inclusion levels showed comparable intake to the control groups; however, final body weight was not significantly affected at any supplementation level. In contrast, feed conversion ratio was significantly ($P < 0.05$) improved at all inclusion levels, with greater improvements observed at 300 and 600 mg/kg compared to the control. Salama *et al.* (2023) reported that Oregano essential oil supplementation in broilers reduced feed intake by 3.72% (300 µl/kg) and 6.52% (600 µl/kg), increased final body weight by 4.28% at 600 µl/kg and improved feed conversion ratio by 9.09% at 600 µl/kg compared to control. Ruan *et al.* (2021) reported that supplementation of broiler diets with Oregano essential oil increased average daily feed intake by 5.07% at 300 mg/kg (4349 g vs. 4275 g in control) and improved final body weight by 4.92% at 150 mg/kg (304.3 g) and 5.55% at 300 mg/kg (306.3 g) compared to control (289.3

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g). Cetin *et al.* (2022) reported that supplementation of broiler diets with oregano and rosemary essential oils had no significant effect on feed intake, but the combination of 200 mg/kg each (OR2) significantly increased final body weight by 6.94% (2801.25 g vs. 2606.98 g) and improved feed conversion ratio by 4.17% (1.68 vs. 1.75 g/g) compared to control. Amer *et al.* (2021) reported that supplementation of broiler diets with a blend of glycerol monolaurate and Oregano essential oil had no significant effect on feed intake, but the 0.75% blend (T4) significantly increased final body weight by 9.86% (2046.04 g vs. 1844.22 g) and improved feed conversion ratio by 11.2% (1.61 vs. 1.79 g/g) compared to control, indicating a synergistic effect at this inclusion level. Overall, dietary supplementation of broiler diets with oregano essential oil, particularly at 300–600 mg/kg and in combination with other additives, consistently improved growth performance by increasing feed intake (up to 8.17%), final body weight (4.28–9.86%) and feed conversion efficiency (up to 11.2%), highlighting its effectiveness as a natural growth promoter in poultry production.

Effect of Oregano essential oil on Carcass Characteristic

Oregano essential oil positively influences carcass characteristics in broilers by improving muscle deposition, enhancing dressing percentage and modulating fat accumulation. Peng *et al.* (2016) reported that supplementation of broiler diets with 600 mg/kg Oregano essential oil significantly improved carcass characteristics, including a 4.98% increase in dressing percentage, higher eviscerated rate, breast and leg muscle percentages and a 19.8% reduction in abdominal fat compared to control. Eler *et al.* (2019) reported that supplementation of broiler diets with 300 mg/kg Oregano essential oil significantly increased dressing percentage by 1.27% compared to control, while other carcass parameters, including breast, liver, gizzard and heart percentages, were not significantly affected. Elbaz *et al.* (2025) reported that supplementation of broiler diets with 300 mg/kg Oregano essential oil combined with probiotics (POE) significantly increased dressing percentage by 6.19% compared to positive control (PCO), while breast, abdominal fat and liver percentages were not significantly affected. Supplementation of broiler diets with Oregano essential oil, particularly at 300–600 mg/kg, alone or in combination with probiotics, consistently improved carcass quality by increasing dressing percentage (1.27–6.19%) and enhancing eviscerated and muscle yield, while reducing abdominal fat in some cases, demonstrating its positive effect on overall carcass composition and meat quality.

Effect of Oregano essential oil on Economy

Oregano essential oil positively impacts the economic performance of broiler production by enhancing growth and feed efficiency, which translates into higher returns

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without increasing production costs. Amer *et al.* (2021) reported that supplementation of broiler diets with a 0.75% blend of glycerol monolaurate and Oregano essential oil (T4) significantly increased total return per bird by 9.73% and performance index by 19.2% compared to control, while net profit, total costs, feed costs, economic efficiency and feed cost per kg gain were not significantly affected. Salama *et al.* (2023) reported that supplementation of broiler diets with 600 µl/kg Oregano essential oil (T3) significantly increased final body weight, total return per chick, total revenue per chick, economic efficiency (11.1%) and relative economic efficiency (10%) compared to control, while total feed cost and total cost per chick were not significantly affected. Dietary supplementation with Oregano essential oil, alone or in combination with other additives, consistently improved economic returns in broiler production by increasing revenue and efficiency (up to 19.2%), while maintaining comparable feed costs, highlighting its potential to enhance profitability without additional production expenses.

CONCLUSIONS

Oregano essential oil is a potent natural alternative to antibiotic growth promoters in broiler production. Its bioactive compounds, particularly carvacrol and thymol, contribute to improvements in feed intake (4–8%), body weight (4–10%) and feed conversion ratio (4–9%). In addition to enhancing growth performance, Oregano exhibits strong antimicrobial and antioxidant properties, which help boost immunity and reduce the risk of diseases in poultry. The optimal inclusion level of Oregano essential oil in broiler diets is 300–600 mg/kg feed, balancing biological efficacy with economic efficiency. Economically, supplementation with Oregano, either alone or in combination with other additives, reduces feed cost per kg gain and enhances overall profitability, making it a valuable strategy for sustainable and productive broiler farming.

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