

# From Aroma to Agriculture: Essential Oils as Game Changers in Poultry Industry Part I

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## Abstract

This review examines using essential oils (EOs) as an alternative approach in poultry farming to clarify their beneficial roles. The discussion introduces current challenges within the poultry industry, from antibiotic resistance and environmental concerns, setting the context for natural feeding strategies. EOs are characterized by diverse bioactive compounds such as terpenes and phenolics, known as powerful alternatives due to their strong antimicrobial, antioxidant, and growth-stimulating properties. Their chemical composition and biological activities can offer insights into their mechanism of action in bird species, specifically poultry. In the context of poultry production, the review underlines how EOs enhance growth performance, support immune responses, and improve feed efficiency. Their role in modulating gut health and potentially improving product quality was discussed herein. Combining these natural substances into poultry farming can address the growing environmental concerns. In this overview, we focus on EOs as a novel and progressive option in poultry farming, aiming to harmonize environmental sustainability with agricultural efficiency.

**Keywords:** Essential oils, growth promotion, nutrition, poultry performance, weight gain.

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## 1. Introduction

Historically, meat has played a crucial role in human diets, and its significance persists in contemporary food consumption patterns. The preference for poultry continues to elevate in response to its escalating global demand. Global meat production has more than tripled over the past five decades; considering statistical studies from 2018, the meat production figure stood at approximately 340 million tons [1]. Looking forward to 2050, projections indicate that a doubling of the food supply — an increase above 102% — will be needed to satisfy the ongoing demand [2]. According to the recent publication, the current market presents approximately 3,000

varieties of EOs derived from at least 3,000 species of plants [2, 3]. Of these, about 300 possess commercial significance due to their widespread utility. The annual production of EOs reaches an impressive volume of 40,000 to 60,000 tons, valued at roughly 700 million U.S. dollars, reflecting a substantial increase in the global market demand [3, 4].

Numerous reports suggest that Europe's Mediterranean region, alongside China, Central Asia, India and South America, is home to a rich diversity of aromatic plants, calculating up to ≈ 3,000 species [1, 2]. These plants are predominantly found within specific botanical families: *Apiaceae*, *Asteraceae*, *Lamiaceae*, *Lauraceae*, *Myrtaceae*, *Poaceae*, *Rutaceae*, and *Zingiberaceae*. Among these, the most prominent genera — *Origanum*, *Rosmarinus*, *Thymus*, and *Ocimum* — are all members of the *Lamiaceae* family, which is frequently preferred as a source for essential oil

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production, primarily due to their rich aromatic compound content [2]. The chemical composition of these EOs can be broadly categorized into terpenes, terpenoids, and phenylpropenes, each contributing to the distinct characteristics and therapeutic properties of the oils.

In poultry production, the use of EOs has been correlated with improved health and productivity indicators, such as enhanced growth performance, better FCR, and improved meat and egg quality [5-8]. The administration of EOs into the diets of laying poultry has yielded substantial benefits in terms of egg production and egg quality [9]. Therefore, this paper aspires to provide a critical and integrative review of the prospects of EOs in poultry farming, evaluating their impact and discussing the potential of integrating these natural substances into the poultry sector. Through a literature analysis of recent studies and findings, this manuscript aims to provide extensive insights into the roles and effects by which EOs can redefine poultry production within sustainable frames.

## 2. Composition and Sources

The source plants for these EOs are as varied as their uses and benefits. They are typically obtained from the leaves, stems, flowers, bark, or roots of plants through processes such as steam distillation or cold pressing. For example, the *Origanum* genus, particularly oregano (*Origanum vulgare*), is recognized for its oil rich in carvacrol and thymol, substances known for their strong antimicrobial and anti-inflammatory properties. *Thymus*, such as Thyme (*Thymus vulgaris*), yields an oil with a high concentration of thymol, which can help reduce bacterial load in the poultry gut. The EO derived from dried thyme predominantly comprises monoterpenes, with thymol and its phenol isomer carvacrol being the primary components [10]. In addition to these, thyme is also rich in phenolics, biphenylic compounds, and flavonoids, all of which are known to possess antioxidative properties [10].

*Cinnamomum*, where Cinnamon is derived, contains cinnamaldehyde, which has been studied for its growth-promoting and antimicrobial effects. *Rosmarinus*, especially Rosemary (*Rosmarinus officinalis*), produces oil for its antioxidant properties, which may improve meat preservation by slowing down oxidation processes

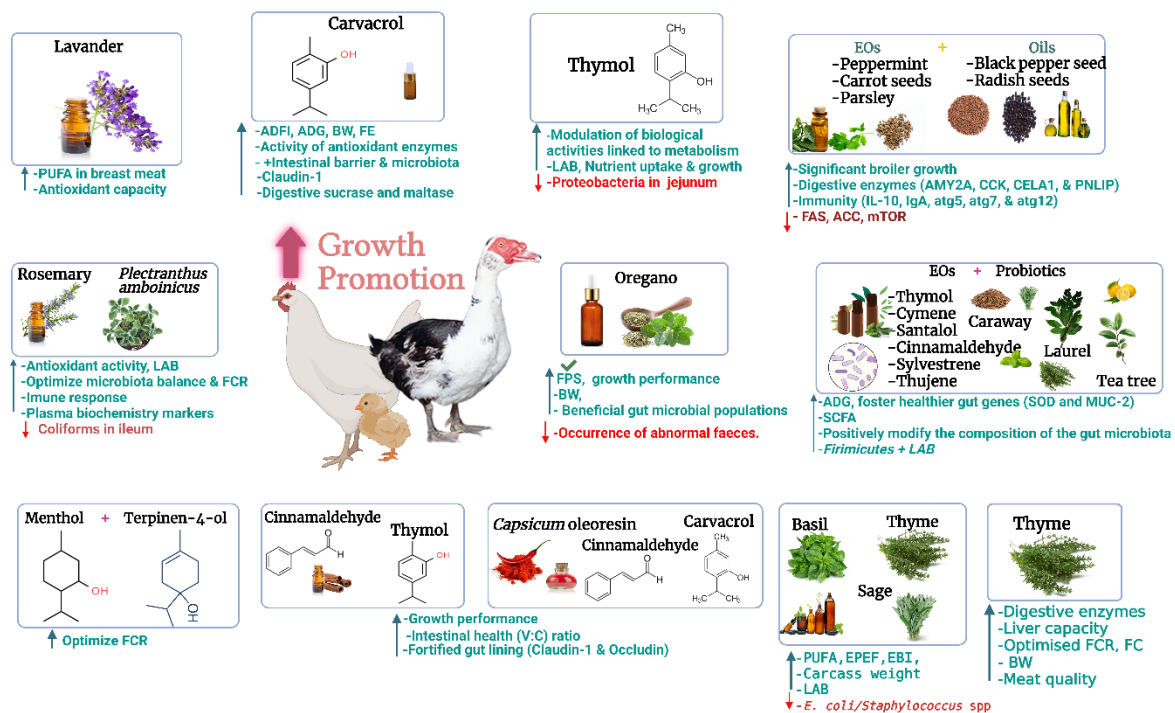
[11]. Peppermint (*Mentha piperita*), being a prime example, is valued for its menthol content and its positive effects on the digestive system of poultry [12]. Terpenoids, oxygen-containing derivatives of terpenes, include menthol from peppermint, which has been observed to soothe the digestive tract, and cineole from eucalyptus, which possesses expectorant properties that can aid respiratory health in poultry [13]. Phenylpropenes like eugenol and anethole, sourced from cloves and anise, respectively, have been shown to possess strong antiseptic and anaesthetic properties [14]. These compounds can contribute to the control of pathogenic bacteria and enhance the overall well-being of poultry. Linalyl acetate, an ester found in lavender EO, contributes to the oil's anti-inflammatory and analgesic properties. These properties could help manage minor pain and discomfort in poultry, which can arise from routine handling or environmental stressors [15]. These constituents offer various benefits for avian health, contributing to their overall well-being and potentially enhancing their performance. Incorporation of thyme in poultry diets at a level of 2% has been found to lower concentrations of yolk malondialdehyde (MDA), a marker of oxidative stress, and decline levels of undesirable blood lipids such as cholesterol (COL) and triglycerides (TG) [10]. This lipid-lowering effect may be attributed to inhibiting the enzyme HMG-CoA reductase, a key enzyme in COL biosynthesis, thereby leading to a decrease in COL production. Thyme extracts also contribute to the improvement of oxidative stability in broiler meat. They work by intercepting and terminating the chain reactions of free radicals, which in turn enhances the shelf-life and quality of the meat by reducing rancidity [10]. The mechanism by which thyme achieves this includes the stimulation of intramuscular fat and the deposition of flavour-enhancing amino acids [16]. Thymol and carvacrol have been documented to boost growth performance in broilers, by enhancing the activities of digestive and antioxidant enzymes, as well as by slowing down lipid peroxidation, which collectively contributes to better health and meat quality in broilers [16].

## 3. Poultry Production and Growth Promotion

Recent meta-analytical research corroborates that EOs are potential growth promoters in poultry

farming, indicating that their inclusion in feed could lead to improved productivity [17]. The main effects of EOs on poultry production and

growth promotion from the recent findings is depicted in figure 1.



**Figure 1.** The illustration of the effects of different EOs on the production and growth-promoting indices in poultry. Symbol ↑ - represent increases or enhancement of investigated parameter. Symbol ↓ - represent a reduction, decrease or downregulation of reported measured variable. Created with *Biorender.com*

The following remarks are particularly relevant given the ongoing search for alternatives to traditional antibiotics and growth promoters. The economic advantage of utilizing EOs, considering their impact on growth metrics, has been deemed promising, suggesting that they offer a cost-effective strategy to enhance the overall efficiency of poultry production systems. Basil, thyme, and sage EOs, when included at a 0.05% level in the diets of broiler chickens, serve effectively as phytochemical additives during the grower-finisher phases by notably expanding the European Production Efficiency Factor (EPEF), European Broiler Index (EBI) and carcass weight [18]. This inclusion not only enhances production performance and the birds' antioxidant status but also enriches the thigh meat with polyunsaturated fatty acids (PUFA). Additionally, these EOs positively modulate the gut microbiota, leading to an increase in beneficial lactobacilli in the intestine and cecum while concurrently declining populations of pathogenic bacteria like *Staphylococcus* spp. and *E. coli*. The incorporation

of *Lavandula angustifolia*, commonly known as lavender, into the diets of broiler chickens has beneficial effects on meat quality [19]. The enhancement of breast meat with PUFAs due to lavender supplementation is noteworthy, as PUFAs are considered beneficial fats that can improve human health, contributing to better cardiovascular and brain function. Moreover, the increase in antioxidant capacity suggests that the meat from these chickens might be more resistant to oxidative spoilage, potentially extending shelf life and reducing the risk of rancidity. The fact that the liver histomorphology remained normal in the lavender EO-supplemented groups, akin to the control group, is a positive sign that lavender EO does not induce any histopathological changes to liver tissue at the doses (200, 400, and 600 mg kg<sup>-1</sup>) provided [19]. Enhancing the profile of fatty acids and the antioxidant status of the meat without adverse effects on the carcass or internal organs indicates that lavender could be a valuable addition to poultry diets, especially considering the growing consumer demand for food products

with added health benefits [19]. This could also enhance the market value of the meat due to its enriched nutritional profile and improved consumer acceptance.

In a controlled study, yellow-feathered broilers receiving feed supplemented with EOs containing carvacrol (12 g/kg) and thymol (23 g/kg) at concentrations exhibited significant improvements in average daily feed intake (ADFI), average daily gain (ADG), as well the body weight (BW) across various growth phases—days 1 to 21, 22 to 42 and 1 to 48 [20]. These birds also demonstrated a reduced feed-to-gain (F: G) ratio compared to those on a basal diet during days 22 to 42 and 1 to 48, indicating enhanced feed efficiency (FE). In addition to growth metrics, the birds fed diets augmented with 400 mg/kg and 600 mg/kg of EOs showed notable improvements in the activity of antioxidant enzymes and intestinal barrier function on day 21, exceeding the performance of the control group [20]. Other exploration into the use of EOs in poultry nutrition, a blend of parsley, peppermint, and carrot seed oils, when integrated with black pepper oil (BPO) or combined with radish seed oil (RSO) at a concentration of 0.5 g/kg in the diet, was observed to enhance broiler growth significantly [7]. This enhancement was attributed to the blend's ability to stimulate the expression of genes linked with digestive enzymes (AMY2A, CCK, CELA1, and PNLIP), thereby improving nutrient digestion. Specifically, adding BPO or RSO to the EO blend at 0.5 g/kg diet was noted to upregulate the gene expression of PNLIP, a critical enzyme for lipid digestion, and concurrently downregulate genes involved in fatty acid synthesis, namely FAS and ACC. Such finding points to the modulation of lipid metabolism in favour of reduced lipogenesis. Furthermore, the EOs blended with RSO BPO were found to be more efficacious in strengthening the immune response compared to the control groups, as evidenced by the increased expression of genes implicated in autophagy (IL-10, IgA, atg5, atg7, and atg12). Such upregulation suggests inhibiting the mechanistic target of the rapamycin (mTOR) pathway, an indicator of enhanced cellular immunity. This study provides intriguing insights into the potential immunomodulatory and metabolic benefits of EO supplementation in poultry diets [7].

Feed Passage Syndrome (FPS) in broilers, known by various other terms such as rapid feed passage

syndrome or malabsorption syndrome, is characterized by undigested feed in the feces [21]. Liquid excreta and litter can often accompany this, although in some cases, the droppings may appear normal yet still contain undigested feed. FPS concerns poultry producers as it indicates a bird's failure to effectively digest feed or absorb nutrients, directly impacting the feed conversion ratio (FCR). Since FCR is a critical factor in the cost-effectiveness of poultry production, FPS can lead to economic losses due to poor FCR and inconsistency in bird growth and health [21]. Martinez and colleagues conducted a study demonstrating the efficacy of oregano EO as an additive in drinking water (300 ml/1 000) for broilers suffering from FPS [21]. Their findings under practical field conditions revealed that oregano EO notably decreased the occurrence of abnormal feces. The treated birds exhibited firmer droppings with less evidence of undigested feed, which is a symptom commonly associated with FPS. Furthermore, adding oregano EO was associated with improved BW gain, suggesting that this natural additive could be beneficial in managing FPS in poultry and enhancing growth performance. The research team posited that the oregano EO exerted a beneficial impact on broilers afflicted with FPS by leveraging the antimicrobial properties of its secondary metabolites, such as carvacrol [21]. These metabolites not only act against harmful microbes but also promote the regeneration of enterocytes, which are cells lining the intestinal wall [22]. This effect is consistent with previous observations where oregano EO was administered to broilers under experimental conditions simulating FPS [21, 23]. The observed reduction in gut dysbacteriosis—a disruption of the normal microbiota—is in line with the selective microbial action of oregano EO [21, 23]. It preferentially targets pathogenic bacteria while promoting the proliferation of commensal and beneficial gut microbial populations, acting similarly to a probiotic. This dual mechanism of antimicrobial and probiotic-like effects likely contributed to the positive outcomes seen in the characteristics of the broilers' excreta [21, 23]. Additionally, the ISA Brown and Bovans Brown breeds show optimal FCR when their diets are enhanced with EOs where the primary bioactive compounds are menthol and terpinen-4-ol, respectively. Investigations into poultry nutrition have revealed

that incorporating thyme in concentrations of 1 to 5 g/kg into the diets of broilers boosts the production of digestive enzymes and enhances the liver's capacity for nutrient processing, leading to more efficient growth and development in poultry [10]. This enhancement was reflected in elevated feed consumption, greater efficiency in FCR, and an overall increase in BW. Moreover, the use of thyme has been associated with an improvement in the proportion and quality of meat from processed birds [10].

Hosseinzadeh and collaborators have recently found that the inclusion of 100 mg/kg rosemary EO improved FCR in the starter phase, indicating more efficient feed utilization [24]. Additionally, EOs rosemary and *P. amboinicus* EOs at the administered dosages (100-200 mg/kg) significantly decreased coliform populations in the ileum while increasing counts of beneficial LAB. The research concluded that *P. amboinicus*, in particular, exhibited a potent ability to enhance antioxidant activity, optimize the balance of intestinal microbiota, improve intestinal morphology, strengthen the immune response, and positively influence plasma biochemistry parameters in broiler chickens, which indicates that *P. amboinicus* could be a promising feed additive to improve the overall health and performance of poultry [24]. Congruently, diets enriched with 150 mg/kg thymol combined with organic acids (2 g/kg citric acid or butyric acid) lessened the relative presence of specific *Proteobacteria* in the jejunum of Cobb broilers and fostered the establishment and proliferation of advantageous bacterial groups such as *Lactobacillus*, and *Bacteroidia* in the gut, and impacted nutrient uptake and growth in broilers by modulating metabolic-related biological activities [25]. Close growth performance increasing effects were observed for Muscovy ducks, when they received in their diets 200 mg/kg of EOs with the main constituents represented by 3% cinnamaldehyde, 5% carvacrol and 2% capsicum oleoresin [26]. EOs specifically those with concentrations of cinnamaldehyde (54 g/kg) and thymol (6 g/kg) at dosages of 500mg/kg and 1000 mg/kg, has demonstrated a positive impact on the growth performance of meat-type ducks [27]. This dietary supplementation was associated with significant improvements in intestinal health, as evidenced by increased villus heights and a statistical improvement (V: C) in the duodenum

and jejunum, which are critical for nutrient absorption [27]. Additionally, there was a notable upregulation in the expression of proteins crucial for maintaining the intestinal barrier, such as Claudin1 and Occludin, indicating a fortified gut lining and potentially enhanced overall health status of the ducks.

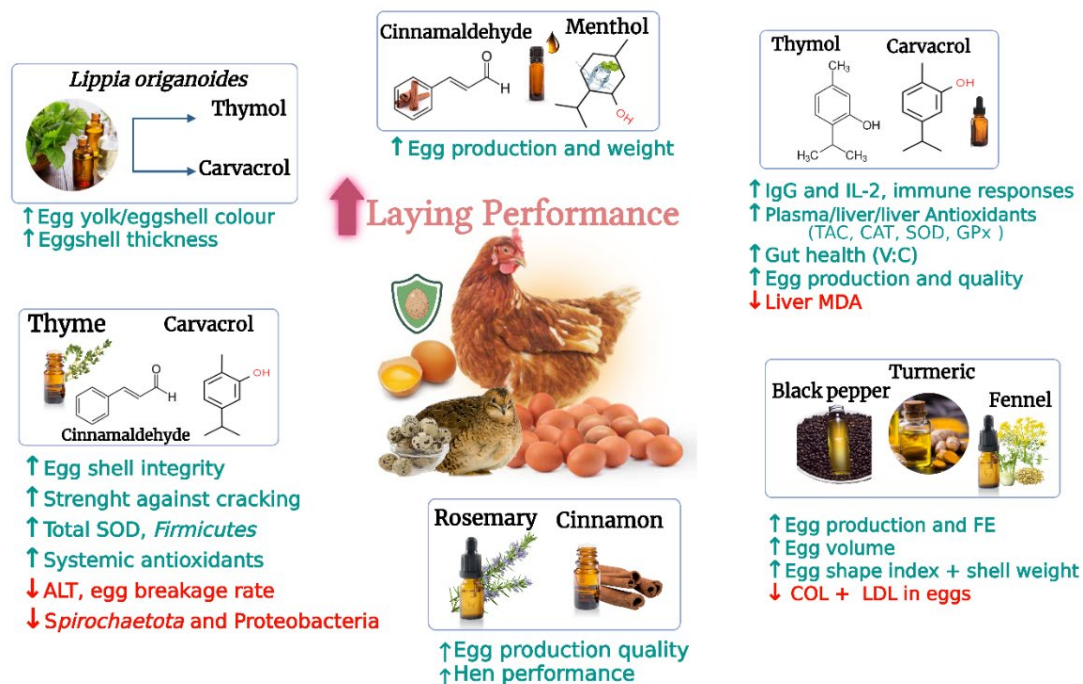
Further studies have indicated that the concomitant use of probiotics, such as *Bacillus subtilis* and *Bacillus licheniformis*, along with EOs from an array of herbs and spices — including basil, caraway, laurel, lemon, oregano, sage, tea, and thyme — can yield positive outcomes in broiler chicken production [28]. The predominant bioactive constituents identified in these EOs were cymene (31.4%), thymol (18.3%), santalol (10.2%), cinnamaldehyde (3.2%), sylvestrene (1.88%), and thujene (1.6%). These compounds collectively appear to enhance ADG, foster healthier gut gene (SOD and Mucin-2 [MUC-2]) expression profiles, elevate levels of beneficial short-chain fatty acids [SCFA] (2-methylbutyric acid and 3-methylbutyric acid), and favourably modify the composition of the gut microbiota. Concurrently, caecal microbial evenness was statistically increased, and there was a notable rise in the prevalence of the phylum *Firmicutes*, which is often associated with healthy gut microbiota. Particularly, the treatment promoted the proliferation of the beneficial genus *Lactobacillus*, whose abundance was directly linked with higher levels of the SCFAs above. These SCFAs were, in turn, positively associated with the structural development of the duodenum and ileum, as reflected by increased villus height

#### 4. Benefits of Essential oils on egg quality.

The latest meta-analysis indicates that laying hens of the Lohmann Brown, ISA Brown, or Bovans Brown breeds yield the most favourable outcomes regarding production and egg weight when their diets are supplemented with menthol or cinnamaldehyde [29]. The dietary bird inclusion of EOs comprising carvacrol, thyme, and cinnamaldehyde at respective concentrations of 2.5%, 5%, and 2.5% (300 mg/kg) in the diet of laying hens has been associated with a notable enhancement in eggshell integrity [5]. The study disclosed a statistically significant decrease in egg fragility, as evidenced by a lower incidence of egg breakage and increased strength required to crack

the eggshells. Concurrently, the hens receiving the EO supplementation displayed a reduction in serum alanine aminotransferase (ALT) levels, suggesting a potential hepatoprotective effect or overall improved physiological state. Moreover, the EO-supplemented diet was correlated with an elevation in the systemic antioxidant defences of the hens, including an increase in total SOD. Notably, the supplementation was linked to an increased presence of the bacterial groups *Firmicutes*, *Intestinimonas*, and *Megamonas*, along with a decreased occurrence of *Spirochaetota* and Proteobacteria. These shifts in microbial populations could reflect a positive modulatory impact of EOs on gut health and function [5]. Powdered supplement with a 16% essential oil content derived from *L. organoides*, providing 8% thymol and 4.9% carvacrol per kilogram of the product after administration to 70-week-old Isa Brown laying hens, at 150 ppm of this essential oil blend in their diet improved yolk colour, eggshell thickness, and eggshell colour [30]. In the research conducted to evaluate the impact of palygorskite composite [EOs-PGS] enriched with carvacrol and thymol ( $\approx 15\%$ ) at a concentration of 0.75 g/kg, the focus was on determining the influence this supplementation had on various aspects concerning laying hens [31]. Hens fed a diet supplemented with the EOs-PGS exhibited notable improvements in several physiological parameters over the control group. Notably, there was an increase in immunoglobulin-G (IgG) and IL-2 levels in the plasma, signifying enhanced immune responses. Additionally, the antioxidant defences of the hens were evidenced by a rise in TAC in both plasma and liver tissues, an uptick in plasma CAT concentration, heightened activity of SOD in the liver, and increased GPx activity in the spleen. The results were further corroborated by diminished MDA levels in the liver, indicating reduced oxidative stress. Finally, the supplementation appeared to positively influence gut health, as suggested by a potential reduction in the crypt

depth of the ileum and duodenum and an elevation in the villus height to crypt depth ratio (V:C) in the ileum—markers of improved intestinal structure. From a production standpoint, the supplemented diet resulted in better egg production, improved egg quality, and stronger antioxidative and immune functions. Based on the outcomes, the researchers recommend a supplementation level of 0.75 g/kg EOs-PGS in the diets of laying hens for optimal benefits [31]. Other authors have reported rosemary and cinnamon EOs attributing the similar significant effects on egg production quality and on overall hen performance [10]. The findings suggest that utilizing rosemary essential oil as an *in-ovo* delivery at 1  $\mu\text{L}$  per egg may serve as a viable growth-promoting alternative in poultry management. This particular concentration significantly enhanced both hatchability and the relative weight of quail (*Coturnix coturnix japonica*) chicks at birth [32]. Contrastingly, a higher concentration of 3  $\mu\text{L}$  per egg was found to be detrimental, with pronounced negative impacts on embryonic survival, indicating a narrow margin of safety for the use of rosemary oil in this context. Samantaray and Nayak have recently evaluated the effects of black pepper, fennel, and turmeric EOs at 0.5 % on the performance of Broiler chickens and egg layers [33, 34]. The results indicate black pepper, turmeric, and fennel, are both economically viable and safe for broilers and laying chickens. These enhancers have led to notable improvements in various parameters of poultry production. Specifically, there was a marked increase in hen-day egg production and FE, alongside better egg volume, egg shape index and shell weight. Importantly, these dietary additions also contributed to the health aspect of egg consumption, as there was a significant reduction in egg COL and LDL levels [33, 34]. To summarize, EOs attribute the similar significant effects on egg production quality and on overall hen performance and are illustrated in figure 2.



**Figure 2.** Benefits of various EOs on egg quality and hen laying performance. Symbol ↑ - represent increases or enhancement of investigated parameter. Symbol ↓ - represent a reduction, decrease or downregulation of reported measured variable. Created with *Biorender.com 2*.

## 5. Conclusion

EOs have demonstrated a capacity to improve AVG, feed intake, and FCR, reflecting their role as growth promoters. This is particularly relevant as the industry navigates away from traditional antibiotics towards more sustainable and consumer-acceptable practices. The functional attributes of EOs, such as improving the antioxidant status of meat and enhancing the fatty acid profile, align with current trends favouring food products with health-promoting properties. In laying hens, the inclusion of EOs has been correlated with improved eggshell integrity and quality—factors that are vital for economic efficiency and consumer satisfaction. The impact of EOs on the gut microbiota composition reflects their potential to create a favourable gut environment, thereby enhancing nutrient absorption and bird health.

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