

Review

Honeybee and Plant Products as Natural Antimicrobials in Enhancement of Poultry Health and Production

Erinda Lika ¹, Marija Kostić ², Sunčica Vještica ³, Ivan Milojević ⁴ and Nikola Puvača ^{5,*} 

¹ Faculty of Veterinary Medicine, Agricultural University of Tirana, Koder Kamez, 1029 Tirana, Albania; elika@ubt.edu.al

² Faculty of Hotel Management and Tourism Vrnjačka Banja, University of Kragujevac, Vojvodanska Ulica bb, 36210 Vrnjačka Banja, Serbia; marija.kostic@kg.ac.rs

³ The Faculty of Applied Ecology, University Metropolitan Belgrade, Požeška 83a, 11000 Belgrade, Serbia; suncica.vjestica@futura.edu.rs

⁴ Ministry of Defense, The Human Resource Sector, Nemanjina 15, 11000 Belgrade, Serbia; drimilojevic@gmail.com

⁵ Department of Engineering Management in Biotechnology, Faculty of Economics and Engineering Management in Novi Sad, University Business Academy in Novi Sad, Cvečarska 2, 21000 Novi Sad, Serbia

* Correspondence: nikola.puvaca@fimek.edu.rs; Tel.: +381-65-219-1284

Abstract: The quality and safety attributes of poultry products have attracted increasing widespread attention and interest from scholarly groups and the general population. As natural and safe alternatives to synthetic and artificial chemical drugs (e.g., antibiotics), botanical products are recently being used in poultry farms more than 60% of the time for producing organic products. Medicinal plants, and honeybee products, are natural substances, and they were added to poultry diets in a small amount (between 1% and 3%) as a source of nutrition and to provide health benefits for poultry. In addition, they have several biological functions in the poultry body and may help to enhance their welfare. These supplements can increase the bodyweight of broilers and the egg production of laying hens by approximately 7% and 10% and enhance meat and egg quality by more than 25%. Moreover, they can improve rooster semen quality by an average of 20%. Previous research on the main biological activities performed by biotics has shown that most research only concentrated on the notion of using botanical products as growth promoters, anti-inflammatory, and antibacterial agents. In the current review, the critical effects and functions of bee products and botanicals are explored as natural and safe alternative feed additives in poultry production, such as antioxidants, sexual-stimulants, immuno-stimulants, and for producing healthy products.

Keywords: honeybee; medicinal plants; quality; antimicrobials; poultry; health



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1. Introduction

The poultry industry has recently faced many challenges, including economic recession, climate change, disease, and overuse of antibiotics. Enhancing animal welfare, production, and health is a significant request for all poultry farms and provides safe and organic products to consumers [1]. Organic production refers to the final product quality and extends to the whole production process under high quality and security control [2,3]. Therefore, today's global trend is to lessen the usage of synthetic prophylactic and therapeutic drugs (such as antibiotics) in poultry farms and find safe and healthy natural replacements [4,5]. The prospect of using new natural materials as dietary supplements in poultry diets instead of antibiotics has been recently studied [6]. These materials have to allow the production of safe and high-quality food. For decades, antibiotics were commonly used in poultry farms to preserve the gut ecosystem's equilibrium and improve chicken growth [7]. The overuse of these antibiotics in poultry farms, as growth promoters for improving feed conversion ratio and growth, has resulted in several adverse effects such as the development of antimicrobial resistance (AMR) and transference, and the residues

remained in consumed meat [8–11]. Several strategies have been applied to deal with this global trend. One of these strategies is to use botanicals as natural substances in poultry production to improve poultry welfare and produce organic meat and eggs [12]. The botanical products can be defined as a natural substance derived from natural products such as plant extracts, fruits, and bee products, added to the animal diet to provide medical or health benefits, including preventing or treating a disease [13–15]. Botanicals appear to have a wide variety of uses in the nutrition and production of poultry [16,17]. In various ways, they are distinct from other dietary supplements, such as their ability to play positive biological roles in an animal's body and their capability to improve its health status without leaving any traces in consumed meat [18–21]. The probable mechanism of action of plant products has been found to be through their beneficial effect on gut microflora by reducing the number of pathogenic organisms, resulting in increased nutrient availability for the host [22–25]. Due to their nutritional and medical properties, herbal and bee products are now used as dietary supplements in poultry production on a large scale [26–32]. Additionally, they are progressively used for *in vivo* feeding techniques as multiple functions such as nutrients for growth and immune stimulation in young chicks [33]. Because the significant benefits in poultry production of both products originated from bees and plants, we decided to unify those products in this review. Furthermore, those products express their efficacy in terms of meat performance, carcass traits, meat quality, immunity, egg quality, and blood parameters, along with the costs and returns on investment to establish the usefulness as an alternative to antibiotics growth promoters, improving their importance.

2. Biological Functions of Botanicals

Botanicals, in general, are natural chemical components with a significant part in the modification and maintenance of normal physiological activities that promote the health of the host [34–36]. They can be divided into botanicals that are still under investigation, such as plant essential oils, and those whose mode of action is supported scientifically [37]. Due to their considerable growth and health benefits, botanicals are widely used in poultry diets as commercial additives and alternative feed supplements to improve animal production and welfare [38]. A healthy gut is generally the cornerstone of optimal poultry growth performance [39]. Sugiharto [40] found that gut health could be affected by various factors. When gut health and function are damaged, the digestion and absorption of nutrients are impacted, which impacts the growth and productivity of poultry. On the other hand, when they are enhanced, the growth and productivity of poultry are improved. Sugiharto [40] also concluded that botanicals could improve the gut ecosystem and the immune functions of poultry and result in growth promotion and prevention or treatment of enteric infections. Botanicals can positively affect the balance of intestinal microbiota, which play a vital role in regulating metabolism, intestinal epithelial proliferation, and vitamin synthesis [41–44]. Many botanicals, in the form of prebiotics, probiotics, and symbiotics, are used to promote poultry gut health [45].

Additionally, these natural products could help in protecting the host against infectious diseases [46]. Plant essential oils have been used routinely in poultry farms for keeping poultry healthy and enhancing their productive performance [47]. Abo Ghanima et al. [47] showed significant and positive results on layers performance, egg quality, hematological traits, blood chemistry, and immunity with the dietary addition of rosemary and cinnamon essential oils. The experiment was conducted on a total of 5000 ISA brown laying hens during the production stages from 28 to 76 weeks of age; the application of 300 mg/kg of essential oils showed promising results. These essential oils contain active substances that have a beneficial impact on physiological processes and have therapeutic properties such as anti-inflammatory and antibacterial effects [48]. In general, previous literature focusing on the biological activity of botanicals has shown that most studies only discuss the concept of their use as growth promoters and anti-inflammatory and antibacterial agents. Our review discusses other critical biological functions using recent natural products as safe alternative feed additives in poultry production and health. The recent

findings and applications concerning the bee (Table 1) and botanical (Table 2) products as natural supplementations adding in poultry diets for improving poultry productivity and enhancing their immunity are summarized, including their mechanisms of action.

Table 1. Effects of dietary addition of bee products in daily poultry production.

Additive	Poultry Species	Additive Concentrations	Obtained Results	Source
Honey	Japanese quails	22 g/L	Improved weight gain, feed intakes, and lower feed conversion ratio; improved immune system, and blood parameters; improved meat quality	[49–51]
Royal jelly	Laying hens	100–400 mg/kg	Increased egg production, improved welfare, and improved immunity; improved performance, egg quality, serum biochemistry and intestinal morphology	[52,53]
Bee venom	Broiler chickens	10–500 µg/kg	Improved production results, fatty acid composition, and antioxidant capacity; Better early development of chickens' digestive system and a helpful tool against short bowel syndrome	[54,55]
Bee pollen	Laying hens and quails	500–1500 mg/kg	Improved production results and biochemical blood parameters with the dietary addition of 500 mg/kg; improved egg production	[56,57]
	Broiler chickens	0.5–1.5%	performance, blood biochemical and immunological response Enhanced immunity of chickens with dietary addition in the concentration of 1.5%; improved performance, carcass traits and blood parameters	[58,59]
Bee propolis	Broiler chickens	200–400 mg/kg	The dietary concentration of 200 to 400 mg/kg improved blood lipid status	[60]
	Laying hens	250–1000 mg/kg	Increased body weight, egg production, and stimulate immunity; improved hematological and immunological parameters;	[61–63]
	Japanese quails	1000 mg/kg	improved performance, digestibility, egg production and egg quality under different environmental temperatures Retaining the performance and egg production at expedient levels under heat stress conditions; improved productivity of laying Japanese quails	[64,65]

Table 2. Effects of dietary addition of botanicals in daily poultry production.

Additive	Poultry Species	Additive Concentrations	Obtained Results	Source
Fenugreek seeds	Broiler chickens	1–3%	Improved production of chickens with the dietary addition of 1% to 3% of fenugreek seed powder	[66,67]

Table 2. Cont.

Additive	Poultry Species	Additive Concentrations	Obtained Results	Source
Black cumin	Broiler chickens	5–10 g/kg	Improved broiler performance and meat quality by enhancing antioxidant activities and suppressing lipid peroxidation in meat	[68,69]
Ginger	Broilers chickens	2–6 g/kg	Improved oxidative status; improved anticoccidial effects against experimentally induced coccidiosis; improved growth performance, haematological profiles, slaughter traits and gut morphometry	[70–72]
	Laying hens	0.25–0.75%	Improved antioxidant status and performance, decreased egg yolk cholesterol levels	[73]
Turmeric	Laying hens	0.5–3%	Improved performance, serum and egg yolk antioxidant status; improved blood metabolites and production performance characteristics; improved performance, egg quality traits, and blood parameters	[74–77]
	Broiler chickens	0.5–1 g/kg	Under heat stress, dietary addition of 0.5% increased the serum concentration of T3 and T4; improved blood constituents and performance	[78–80]
Thyme	Broiler chickens	1–3% 100–200 mg/kg	Possibility to replace antibiotics in the diet of chickens; Reduction of fat in chicken carcasses; improved growth, lipid oxidation, meat fatty acid composition and serum lipoproteins; improved growth performance	[81–83]
	Laying hens	300 mg/kg	Microbial counts in the crop, small intestine and caecum	[84–86]
	Japanese quails	0.01–1%	Maintain production results, decreased serum glucose level, decrease plasma MDA during the heat stress; improved productive performance, egg quality traits, and blood parameters under cold stress conditions	[87,88]
			Increased antibody titer against sheep red blood cells (SRBC), lymphocyte proliferation, and respiratory bursting ability and decreased the delayed type of hypersensitivity; improved performance, some blood parameters and ileal microflora	

Bee and botanical products express various protective effects when used as a dietary supplement in daily nutrition. Flavonoids, a major group of bee ingredients, are known as potential natural iron chelators and antioxidants. They appeared to play an important role as cardioprotective agents in doxorubicin-induced cardiac toxicity caused by the production of oxygen free radicals. The specific mechanism of action induced by flavonoids found in bee products is not yet fully elucidated. Some findings state that the cardio-protective potential of bee propolis could be associated with the radical scavenging action of caffeic acid phenethyl ester [89]. Dietary supplementation with propolis significantly reduces the serum concentrations of triglyceride, cholesterol, nitric oxide, very low-density lipoprotein (LDL), cholesterol, nitric oxide synthase (NOS), plasma glucose and malonaldehyde in fasting murine models, which improves the circulatory levels of high-density lipoprotein (HDL), cholesterol, and superoxide dismutase activity, indicating that propolis could play a role in normalizing the metabolism of circulatory fats [90]. According to the published data, the components of propolis can have potentially beneficial effects against microbial infections, hypertension, cardiovascular disorders, diabetes, and several chronic diseases. It is confirmed that several therapeutic impacts of bee products are due to their anti-oxidative, immunomodulatory, and anti-inflammatory activities. Some research lies behind the molecular mechanism of bee products' mediated protective effects [91]. Dysfunction of mitochondria is the major factor of ROS production, which leads to hypertension, diabetes, allergies, and asthma. The high production of ROS involves oxidative injury to cellular components (nucleic acids, proteins, and lipids) of tissues. Likewise, several other mechanisms are also involved in the generation of ROS. Enzymatic and non-enzymatic oxidation of polyunsaturated fatty acids such as arachidonic fatty acid. The interaction of unsaturated fatty acids with the trace metal ion Fe³⁺ resulted in the per-oxidation of fatty acids and the intensification of ROS production. ROS are also generated by NADPH oxidase. The components of bee propolis like quercetin, p-coumaric, caffeic, ferulic acids, caffeic acid phenethyl ester, and chrysin block the production of inflammatory mediators by suppressing the expression of lipoxygenases, cyclooxygenases, phospholipase A₂, and nitric oxidase synthase [92]. Additionally, other bee components also inhibited the production of NF-κB by blocking its translocation to the nucleus [93].

Most of the researchers attributed the better performance of the poultry that were fed natural products to an improvement in palatability and a quick digestive effect. They further postulated that because of these natural products, the digestive tract would have been emptied earlier and feed consumption promoted. Ginger has been found to increase the secretion of gastrointestinal enzymes, including lipase, disaccharidase, and maltase [70]. Generally, improved performance may be attributed to the digestive enzymes such as protease and lipase, which are present as part of the plant's natural protective mechanisms. Reports have shown that natural products enhance animals' nutrient digestion and absorption because of their positive effect on gastric secretion, enterokinase, and digestive enzyme activities [94]. Even the dietary addition of natural products to laying hens expressed positive effects in better egg production and mass; the exact mechanism through which egg-laying performance is enhanced is not known. The higher performance of the laying hens may be due to antioxidant, antimicrobial, increased blood circulation, secretion of digestive enzymes, and reduction in feed oxidation. Despite increased levels of antioxidant enzymes and a reduction in MDA concentrations, the mechanism involved is not yet known [74]. Literature has shown that polyphenolic flavonoids in plants are some of the major sources of antioxidant compounds. Some studies have also shown that raw plant materials and single constituents like [6] gingerol have the ability to protect against lipid peroxidation. It is known that natural products and various medicinal plants change the blood metabolites of poultry when used as dietary supplements [95]. Still, the exact mechanisms through which blood metabolites are altered are not known. Research conducted with mice and ginger dietary supplements postulated that (E)-8 beta, 17-epoxylabeled-12-ene-15, 16-dial, a compound isolated from ginger, interferes with cholesterol biosynthesis in the liver homogenates of hypercholesterolaemic mice, causing their reduction. Srinivasan

and Sambaiah [96] reported that feeding laboratory animals with natural plant products significantly elevated the activity of hepatic cholesterol 7- α -hydroxylase, which is a rate-limiting enzyme in the biosynthesis of bile acids and stimulates the conversion of cholesterol to bile acids, leading to the excretion of cholesterol from the body.

3. Bee Products and Their Effects on Health Status and Poultry Productivity

Honeybee products are natural substances synthesized in honeybees (*Apis mellifera*) [97–100]. These products have unique structures rich with active components of enzymes and peptides that have several pharmaceutical characteristics besides their high nutritional value and their significant impact on poultry's physiological and productive performance [101]. These kinds of nutritional and therapy alternatives have been used for centuries, mainly in China and Egypt [102]. According to the results of Babaei et al. [49], the critical active nutrient components of bee products may increase body weight gain, body weight, lymphoid organ weight, and antibody titer of Japanese quails. Rabie et al. [60] indicated that it is imperative to add bee products such as propolis (400 mg/kg diet) or bee pollen (2000 mg/kg) to broiler diets and bee venom (2 mg/L) to broiler's water as alternatives to antibiotics in poultry production. These additives can improve physiological performance, productivity, meat quality, and the development of the poultry immunity system due to their high levels of active enzymes, essential amino acids, vitamins, and minerals, and antimicrobial and immuno-stimulant activities of bee products [103]. Bee products can also increase the fertility of animals by enhancing the cryopreservation of gametes and fertilization [104]. The bioavailability of bee products is greater than that of artificially produced preparations. Research on the use of bee products as nutritional supplements for poultry has generally shown their positive impact on health and productivity [105,106]. A wide range of research has concentrated on the propolis supplementation of layers and broilers in various conditions and age groups. Research has concerned primarily the immune response of the birds, physiological parameters, and weight gain in broilers, as well as the parameters of egg-laying activity and quality of eggs [107].

3.1. Honey

Honey is a naturally sweet liquid produced by honeybees from nectar or plant secretions [108]. Therefore, several natural substances, such as antioxidants, are transferred from plants and accumulated in this product. The bioactive components of honey, including its chemical properties and physical characteristics, make it one of the most important natural products nowadays [109]. Chemically, it is composed of simple sugars: fructose, glucose; minerals: calcium, phosphorus; vitamins: ascorbic acid, riboflavin; enzymes; organic acid: gluconic, butyric; flavonoids and other phenolic and aromatic substances [110]. For its nutritional and therapeutic properties, honey is considered a vital drinking water additive for poultry [111]. The supplementation with honey into the drinking water (20 to 60 g/L) for broiler chickens during the summer seasons can improve some stress indices by more than 10%, body mass over 6%, and immunity over 2%. Haščík et al. [111] have conducted a small study on a total of 240 Ross and 308 broiler chickens to investigate the influence of bee pollen extract, propolis extract, and probiotics on the amino acid profile of chicken meat. Haščík et al. [111] stated that in addition, these bee products did not improve or show any adverse effects in the chicken meat amino acid profile. Another study was performed by Abioja et al. [112] on broiler chickens, with the aim to investigate the growth, mineral deposition, and physiological responses of chickens offered honey in drinking water during the hot-dry season. Investigations have shown that honey did not affect growth but might improve the chickens' welfare when offered up to 20 mL per litre water from d28 to d56 during hot periods. Adekunle et al. [113] investigated the addition of honey to the water of laying pullets through the hot-dry season. The trial was conducted on a total of 120 Isa Brown layers at 28 weeks old in a 16-week experiment supplemented with 10 and 20 mL of honey per 1 L of drinking water. The results of this trial have shown that heart rate was significantly ($p < 0.05$) lower in 20 mL supplemented

hens (300.9 ± 1.70 bpm) compared to 0 mL supplemented hens (313 ± 1.70 bpm). Hens supplied 20 mL had a significantly ($p < 0.05$) higher lymphocyte count (50.6 ± 0.79 %) while hens that received a lower concentration of honey had a significantly ($p < 0.05$) lower basophil count ($3.1 \pm 0.39\%$). Adekunle et al. [113] concluded that the use of honey in drinking water reduced heart rate and basophil count.

3.2. Royal Jelly

Royal jelly is one of the popular bee products widely used as natural food for humans and animals due to its high content of essential nutrients [114]. It is an excellent source of B vitamins, vitamin C, folic acid, and phenolic acids [115]. Royal jelly is also a good source of minerals [116]. It has several important biological functions in the living being, including its effects as an antioxidant, immuno-stimulant, and growth promoter [117]. The antioxidant activity of royal jelly is primarily due to the presence of polyphenolic compounds [118]. It can be used in poultry production to improve the growth, gut health, and immune response and produce high-quality and safe poultry meat [119]. Previous studies focused on supplementing with royal jelly (10 to 200 mg/kg) in poultry diets have shown a significant increase in body weight (7%), egg production (10%), semen quality, and immune levels, as well as producing organic products [120]. Besides, El-Tarabany [52] conducted an experiment to clarify the influence of royal jelly on behavioural patterns, feather cover, egg quality, and some blood haematological indices in laying hens (58–64 weeks of age). Pure royal jelly injected in a concentration of 100 mg/kg, and 200 mg/kg, was used. Results have revealed that the feed consumption and water drinking in the 200 mg/kg group were significantly higher than the control and 100 mg/kg groups. Furthermore, the aggressive pecks, feather pecks, and threatening behaviour in the 200 mg/kg group were significantly lower than the control and 100 mg/kg groups. The effect of royal jelly, propolis, honey, and bee pollen was investigated in comparison to virginiamycin in regards to the performance and immune system of Japanese quail in research by Babaei et al. [49]. An *in vivo* experiment including a control, ethanolic extract of propolis 1000 and 5000 mg/kg, pollen powder 1000 and 5000 mg/kg, royal jelly 100 mg/kg, honey 22 g/L of drinking water, and virginiamycin 150 mg/kg were used in a trial for 42 days.

3.3. Bee Venom

Bee venom is also one of the bee products synthesized in the venom gland of honeybees and has several pharmaceutical and medical characteristics [121]. It consists of various substances, including peptides and enzymes, whereas melittin is the most effective component [122]. It also contains other essential substances, such as apamin and adolapin, which have various medicinal effects such as anti-inflammatory and antibacterial [123]. Therefore, bee venom could be added to the animal diet to provide productive and health benefits, including preventing and treating disease [124]. El-Hanoun et al. [125] and Elkomy et al. [124] reported that bee venom could also be an effective and safe alternative for poultry production instead of artificial sexual stimulants, which could harm consumer's health. It can improve reproductive efficiency, serum quality, and antioxidant status of broiler chickens and their immune response by using small doses (0.1 to 0.5 mg/kg) [121]. Rabie et al. [60] have conducted trials to evaluate the effects of propolis, bee pollen, and bee-venom as eco-friendly alternatives on the productive and physiological performance of broiler chickens. The chicks fed diets containing propolis (200 or 400 mg/kg diet), bee-venom (2 mg/L water), or bee-pollen (2 g/kg diet) showed significantly lower plasma cholesterol and LDL-cholesterol concentration compared to the control and Biox-Y® treatments. Consequently, propolis (200 or 400 mg/kg diet) and bee-pollen (2 g/kg diet) treatments had significantly higher plasma HDL cholesterol concentrations than the control treatment. Broilers fed propolis (200 or 400 mg/kg diet) for six weeks had significantly lower serum AST and ALT concentrations compared to the control treatment [60].

3.4. Bee Pollen

Bee pollen is a fresh form of feed additive and is composed of a range of nutritional and bioactive compounds [30]. Bee pollen has the ability to improve immunity, promote growth, protect intestinal tract health, and improve the quality and safety of poultry products. Also, bee pollen is a natural mixture of pollen grains collected by bee workers and then mixed with nectar and other gland secretions containing active components such as a β -glycosidase enzyme [126]. It has been used as natural growth and health promotion in poultry production due to its high content of amino acids, vitamins, and minerals [127]. Moreover, it is rich in polyphenols and tannins that act as protective agents and potent antioxidants, essential for improving animal health and immunity [128]. Abdelnour et al. [129] concluded that bee pollen could improve the animal's productive performance, including body weight gain. It can reduce daily feed intake by improving the feed conversion ratio [65] while increasing body weight by increasing the small intestinal villi surface of the duodenum, jejunum, and ileum.

Additionally, biochemical blood profiles, kidney functions, immunological parameters, antioxidant status, carcass traits, and meat quality have been improved remarkably by using bee pollen as an addition to broiler diets at the level of 400 to 800 mg/kg [129]. Bee pollen's underlying mechanism for improving carcass and meat quality could be attributed to decreased fat deposition and an increase in amino acid deposition [130]. The dietary addition of bee pollen in the concentration of 400 mg/kg have improved the amino acid profile of breast and thigh muscles, with significantly increased concentrations of tyrosine in the breast and significantly decreased concentrations of proline in breast and thigh muscles, respectively [131]. Trembecká et al. [132] have investigated the influence of bee pollen on the chemical and sensory characteristics of chicken breast meat. Results have shown that diet did not affect the chemical characteristics of chicken meat, except for supplementation with bee pollen and probiotics, which resulted in increased fat content. Further research has shown that the carcass yield values were significantly higher ($p = 0.038$), and the drip loss values were significantly lower ($p = 0.003$) in the experimental groups in comparison to the control group when bee pollen and propolis was used as dietary supplements. In addition, there was a statistically significant difference in b^* skin colour ($p = 0.017$) and b^* chicken breast muscle colour ($p < 0.001$) between the groups of chickens. The study showed that dietary supplementation with propolis and bee pollen has a significant positive effect on the quality of chicken meat [133]. Moreover, supplementation with bee pollen under stress conditions has been shown to reduce oxidative stress markers and improve the animal's antioxidant system [134]. Research has revealed that bee pollen as a natural antioxidant can be used as a supplementation in laying hen diets (1000 to 2000 mg/kg) to improve their production performance, egg production by 4.5%, and enhance egg yolk quality with a decreased total cholesterol concentration by 45%, thereby producing healthy products for consumers [135]. Furthermore, it is recommended to use bee pollen in roosters' diets (1000 mg/kg) to improve the ejaculate volume, progressive motility, live sperm, concentrate per ejaculate, and decrease sperm abnormalities [136].

3.5. Bee Propolis

Bee propolis is a natural resinous substance rich in active enzymes, and it has been recognized for its medicinal and therapeutic properties [137,138]. Aromatic compounds, flavonoids, and phenolics are the core components responding to the biological functions of propolis [139]. Working on propolis as one of the bee products used in poultry production, researchers have reported that it could be effectively added to the Japanese quail diet (500 to 4000 mg/kg) to improve growth performance and egg quality. It could optimize the lipid profile in egg yolk and reduce the total cholesterol concentration by more than 3.5%, respectively [140]. Moreover, it positively affects the antioxidative status of poultry, especially under summer conditions [141]. The authors found that propolis supplementation improved the immune status of poultry and positively affected the plasma levels of calcium (23%), phosphorus (24%), and albumin (17%), in addition to normalizing the

plasma levels of alanine aminotransferase (ALT) and cholesterol [142]. This additive has successfully maintained the performance and egg production of Japanese quail under heat stress conditions at adequate levels [64]. Pieroni et al. [143] have investigated the effects of dietary inclusion of other varieties of propolis, such as the green propolis, on productivity, egg quality, nutrient utilization, and duodenal morphology of 120 Japanese laying quail. Authors have pointed out that the inclusion of green propolis at 1500 ppm in the diet of Japanese laying quail improves productivity, egg quality, nutrient utilization ability, and duodenal morphology [143].

4. Botanicals and Their Effects on Health Status and Poultry Productivity

Medicinal plants possess many natural materials widely used as dietary supplements in poultry production [38]. Due to their nutritional and medicinal properties, they have many positive effects on poultry performance [144]. Phytochemicals, phenols, flavonoids, tannins, and essential oils are found in various botanicals, and their products have several activities inside the poultry body [144]. They can act as digestive enhancers and health promoters for various poultry species such as broiler chickens, Japanese quails, and laying hens [145]. As a result, they play several significant roles in increasing poultry productivity and immunity [146]. Because of the bio-security threats for human and animal health, which come from the escalating resistance of pathogens to antibiotics, the global need to remove antimicrobial growth promoters from animal diets are rising as a very important issue.

4.1. Fenugreek Seeds (*Trigonella foenum L.*)

Fenugreek seeds are known as medicinal seeds that have several therapeutic properties such as antibacterial and anti-inflammatory [147]. They are also rich in protein, fat, carbohydrates, and minerals and contain biotin and trimethylamine, which tend to stimulate the animals' appetite [148]. Studies by Tewari et al. [148] revealed that fenugreek seed dietary supplementation has a positive effect on the activities of the hepatic antioxidant defence enzymes in animals. Galactomannan is the major polysaccharide found in fenugreek seeds and represents approximately 50% of the seed weight [149]. Galactomannan in fenugreek has been identified as an anti-diabetic compound because of its ability to reduce blood glucose levels [150]. Gaikwad et al. [67] concluded that using fenugreek seed powder in amounts 1% to 1.5% as a natural supplement in the broiler diet can improve the feed conversion ratio and increase the live body weights. Furthermore, Yassin et al. [66] concluded that the inclusion of up to 3% fenugreek in broiler diets could improve the average daily gain and carcass characteristics of chickens. Several investigations have suggested that fenugreek seeds may have hypocholesterolemic activity and thus, may be efficient in the treatment of egg yolk cholesterol. Omri et al. [151] have evaluated the effect of dietary incorporation of 3% of fenugreek seed combined with 3% of linseed, 1% of garlic paste, and 0.078% of copper sulphate on laying performance, egg quality, and lipid profile. An experiment on a total of forty-four 41 week-old Novogen White laying hens lasted 42 days. The dietary addition of medicinal plant mix in this small trial showed positive results. The egg weight of hens was not affected by dietary additions of medicinal plants, but the egg yolk cholesterol and blood cholesterol were both reduced. Abdouli et al. [152] evaluated the effects of ground fenugreek seeds given to laying hens at 2, 4 or 6 g/hen/day on laying performance, egg quality characteristics, serum, and egg yolk cholesterol concentrations. A total of forty 52-week-old Lohmann White laying hens were fed for seven weeks in the experiment. The results of Abdouli et al. [152] showed that ground fenugreek seeds reduced blood serum cholesterol but did not affect egg yolk cholesterol. Authors have pointed out that ground fenugreek seeds given to Lohmann White laying hens at up to 6 g/hen/day had no effect on feed intake, laying production performance, and egg quality but reduced the hen's serum cholesterol [152]. A research study was conducted by Abbas [153] to find the effect of fenugreek, parsley, and sweet basil seeds as natural feed additives on broiler performance. Experimentation was performed

on a total of 120 day-old chicks reared for 42 days. Chicks fed basil diets had significantly ($p < 0.05$) heavier body weight than those fed fenugreek diets. Carcass characteristics had no significant differences. A significant reduction occurred in serum cholesterol as compared to control diets. Abbas [153] suggested that the supplementation of broiler chick diets with (3 g/kg) basil or parsley seeds improve product performance.

4.2. Black Cumin (*Nigella sativa* L.)

Black cumin seeds are also known for their medicinal and pharmaceutical properties [154]. They contain alkaloids, volatile oils, antioxidants, and several pharmacologically active substances such as thymol [155]. Martínez Aispuro et al. [156] reported that black cumin promotes poultry production and health and plays a significant role as a natural antioxidant, immuno-stimulant, and anti-cancer agent. Black cumin seed supplementation in daily poultry diets (10 to 30 g/kg) improved nutrient utilization, growth performance, and immune response and reduced the fatty acid content in poultry meat and eggs [157]. Rahman and Kim [158] indicated that black cumin supplementation could improve broiler chickens' production and meat quality by improving antioxidant activities and suppressing lipid peroxidation in meat. Boka et al. [159] performed a study to investigate the effects of different levels of black cumin seeds on performance, intestinal *Escherichia coli* count and morphology of jejunal epithelial cells in laying hens. A total of 100 Leghorn laying hens of 49 weeks old were used in an experiment where hens were supplemented with 0, 1, 2, and 3% of dietary black cumin. Based on the gain results, it has been concluded that supplementation with black cumin improves ($p < 0.05$) eggshell quality, Haugh unit, and feed conversion ratio. This improvement can be addressed as the increase ($p < 0.05$) in egg mass and contemporaneous decrease ($p < 0.01$) in feed consumption. Besides, regardless of supplementation level, dietary inclusion of black cumin decreased *E. coli* enumeration in ileal digesta and improved serum lipid profile and eggshell quality. A previous study conducted by Aydin et al. [160] with a total of 80 laying hens (Hyline-5 White) fed with a dietary addition of 1, 2, or 3% black cumin have shown a similar tendency.

4.3. Ginger (*Zingiber officinale* L.)

Ginger roots have been widely consumed as a herbal medicine with anti-cancer properties in several countries worldwide [161]. They contain essential volatile oils and other compounds, such as zingerone and gingerols, which can stimulate digestive enzymes and microbial activities and improve the antioxidative status of living beings [162]. Therefore, when Zhang et al. [70] have used a level of 5 g/kg ginger powder in broiler diets as nutritional supplementation, it led to the enhancement of antioxidant capacity and serum metabolites. Growing Japanese quails fed ginger supplemented diet (0.125 g/kg) obtained the best results in feed conversion ratios and humoral immunity. Moreover, ginger supplementation helped to optimize the lipid profile in blood serum and improve quails antioxidative status [163]. The use of ginger as an antibiotic replacement in livestock nutrition and welfare improvement may play a basic role in maximizing benefits and preserving poultry productiveness [164]. Oleforuh-Okoleh et al. [165] performed an experiment to evaluate the growth performance, haematological, and serum biochemical response of broiler chickens to aqueous extracts of ginger and garlic. The experiment lasted 56 days and was performed on a total of 80-day-old Marshal Strain broiler chickens supplemented with 50 mL of ginger and garlic in a 1:1 ratio mixture in drinking water. All the investigated parameters were significantly improved at the end of the experiment. On the other hand, a study using 144 one-day-old Arbor Acres broilers was conducted to assess the effects of dried ginger root processed to particle sizes of 300, 149, 74, 37, and 8.4 μm on growth performance, antioxidant status, and serum metabolites of broiler chickens by Zhang et al. [70]. The results of these investigations revealed that reducing the particle size of ginger powder linearly reduced ($p < 0.05$) cholesterol (d 21) and linearly increased ($p < 0.05$) glutathione peroxidase (d 21), total superoxide dismutase (d 42), and total protein (d 21 and 42). Supplementation of ginger at the level of 5 g/kg improved

the antioxidant status of broilers, and the efficacy was enhanced as the particle size was reduced from 300 to 37 μm [70]. Other studies have been conducted to investigate the effect of ginger extract combined with citric acid on the tenderness of duck breast muscles. Even added as a marinade, ginger has expressed positive effects and significantly increased duck breast meat tenderness which could be attributed to various mechanisms such as increased myofibrillar fragmentation index and myofibrillar protein solubility [166].

4.4. Turmeric (*Curcuma longa* L.)

Turmeric is a rhizomatous herbaceous plant belonging to the ginger family [167]. It has been described as a natural polyphenol nutraceutical substance and is widely known for improving oxidative stress and fixing oxidative damage [168]. It can also be used in animal diets to mitigate heat stress [169]. Turmeric or curcumin can eliminate free radicals such as reactive oxygen species (ROS) and reactive nitrogen species (RNS) by activating glutathione (GSH), catalase, and superoxide dismutase (SOD), triggering better responses in the antioxidative mechanisms and inhibiting or neutralizing enzymes generators of ROS [170]. Therefore, it becomes an important antioxidant and medical additive in poultry diets, particularly in tropical regions, where high temperatures throughout the year can lead to reduced egg production, delayed growth, increased disease outbreaks, and mortality [171]. All these problems intensify poultry heat stress [172]. Sadeghi and Moghaddam [173] found that the addition of turmeric powder (0.5%) into broiler diet under heat stress increased serum concentrations of thyroxine (T_4) and triiodothyronine (T_3), the consumption of feed, the average daily gain, and decreased the feed conversion rate of birds. Furthermore, El-Maaty et al. [174] observed that turmeric powder (0.5 g/kg diet) could improve the final body weight (12%), the feed conversion ratio (19%), the digestibility of crude protein (5%), and the high-density lipoprotein (HDL) level (29%), as well as decrease the levels of creatinine, triglycerides, cholesterol (17%), low-density lipoprotein (LDL) (38%), during the heat stress conditions in broiler chickens. Algawany et al. [175] performed a study to evaluate the effects of turmeric for protection against alterations resulted from exposure to endosulfan in broiler chicks.

4.5. Thyme (*Thymus vulgaris* L.)

Thyme is one of the most commonly used herbs worldwide and is an aromatic medicinal plant, belongs to the Lamiaceae family [176]. It extensively uses in human food to add a distinctive aroma and flavour [177]. It is also used in animal diets as an alternative to synthetic drugs such as antibiotics to improve the product performance and the immunity of animals due to its antioxidant, antimicrobial, pharmaceutical, and therapeutic properties [178]. Dry thyme contains approximately 2% of the essential oil that is a mixture of monoterpenes, primarily thymol (2-isopropyl-5-methylphenol) and its phenol isomer carvacrol [179]. It also contains phenolics and some biphenolics and flavonoids, which have been shown to have an antioxidative effect and other benefits to poultry [180]. Thyme extracts are recommended to improve egg quality, particularly the fatty acid profile in yolk [181]. Yalçın et al. [182] found that a diet supplemented with dry thyme leaves (2%) has various beneficial effects on the physiological and productive performance, antioxidant status of laying hens, as well as having a positive effect on egg production quality such as decreasing the yolk cholesterol and total saturated fatty acids concentrations, and increasing the n-3 polyunsaturated fatty acids (PUFAs). It also increases the α -linolenic acid while decreasing palmitic acid percentage in the yolk [181]. Moreover, dietary thyme at 2% can decrease yolk malondialdehyde (MDA), blood serum cholesterol, and triglycerides levels, while the antibody titers against SRBC were increased [182]. Previous studies have shown that dietary thyme supplementation can increase the productivity of poultry (growth performance and egg production) and the humoral immune response without adverse effects on poultry [183–186]. Additionally, investigations have found that dietary thyme supplementation (0.1 to 1%) can play a role as a growth promoter in broiler diets to improve feed intake, conversion ratio, and body weight gain [187]. It can also improve the

dressing percentage and meat quality of poultry. Its underlying mechanism may involve stimulating intramuscular fat and flavour amino deposition and changes in muscle fibre characteristics. Hashemipour et al. [188] reported that phytogetic products containing thymol and carvacrol improved performance, digestive enzyme activities, antioxidant enzyme activities, immune response, and retarded lipid oxidation in broiler chickens. Pournazari et al. [189] performed an investigation to evaluate the effects of the prebiotic, probiotic, and thyme essential oil on growth, organ and carcass traits, and hematology of Ross broiler chicks during 42 days on a total of 560 broilers. Results showed an increase in body weight gain and feed intake when thyme essential oil at 1 g/kg was used [189].

Additionally, thyme is rich in flavonoids, which can increase vitamin C activity, which serves as an antioxidant and, consequently, enhances immune functions [190]. Thus, it plays a vital role in reducing stress on poultry, particularly during the summer months, and increasing feed intake, improving feed metabolism, and decreasing weight loss in poultry, mainly due to heat stress [191]. Essential oils found in thyme can improve the productive performance of the animal by increasing the secretion of digestive enzymes and enhance the use of nutrients through enhanced liver function [192]. El-Ghousein and Al-Beitawi [193] found that the antibacterial activity of thyme could be associated with improved broiler productivity. In addition, Hernandez et al. [194] observed that broilers fed with a thyme-supplemented diet had improved their productive performance, which may be attributed to the improvement of apparent total faecal digestibility and crude protein digestibility. Another study was performed by Nouri [195] to evaluate the effects of chitosan nano-encapsulating mint, thyme, and cinnamon essential oils used in the diet for performance, immune responses and intestinal bacteria population in broiler chickens. A total of 600 mixed-sex, 1-d-old Ross 308 broiler chicks were used in the experiment, which lasted 42 days, during which chickens were supplemented with 0.025%, 0.04%, and 0.055% essential oils, respectively to starter, grower, and finisher diets. Results showed that thyme essential oil improved traits in broiler chickens [195].

5. Conclusions

Bee and botanical products are biologically active substances found in natural products. Whether they are from animal or plant sources, they are essential materials for maintaining better growth performance for animals such as poultry and enhancing their health and welfare.

The present review has focused on bee and botanical products' potential in poultry production as natural growth promoters, antioxidants, anti-inflammatory, and antimicrobial agents' immuno-stimulants, and sexual-stimulants. It has presented the current state of knowledge on the nutritional and therapeutic properties of the most important bee and natural botanical products in poultry diets and summarized the results of previous studies concerning dietary supplements in intensive and modern poultry production.

Bee and botanical supplements can increase the bodyweight of broilers and the egg production of laying hens by approximately 7 and 10% and enhance meat and egg quality by more than 25%.

Many results recommend that poultry have bee and botanical products as additions in their diets as natural alternatives to any artificial chemical material such as antibiotics. These natural substances can be added to the poultry diet individually or mixed to improve several physiological functions of poultry that have the most significant impact on the growth performance, reproductive efficiency, immune-response, and productivity of poultry, which, in turn, will lead to improved poultry welfare and produce healthy and organic products.

Keeping in mind that bee products are rich in several chemical bioactive compounds like polyphenols, steroids, terpenoids, amino acids, and inorganic compounds, and possesses many biological properties, including antiviral, antioxidant, antibacterial, hepatoprotective, antifungal and immuno-stimulating activities, further research on finding the ideal

techniques for the practical application of bee products on a commercial level in poultry farming is still necessary and should be encouraged.

Also, botanical products represent a source of very valuable bioactive compounds with a proven impact on the health, performance, and welfare of poultry. These factors can be influenced by dosage, type, and levels of bioactive compounds, so further investigation should be focused on dosage and depend on trials and correlation effects with bee products to get deeper knowledge and mechanisms of action which will scientifically explain positive results on poultry performance and health support. It is well-known that botanicals have a positive influence as a growth enhancer, antioxidant, immunomodulator, antibacterial. Further, we suggest that the use of botanicals combined with bee products could be used for the alleviation of oxidative stress in farm animals and poultry, thus may be used successfully to overcome stress, but future research in this field is still needed.

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