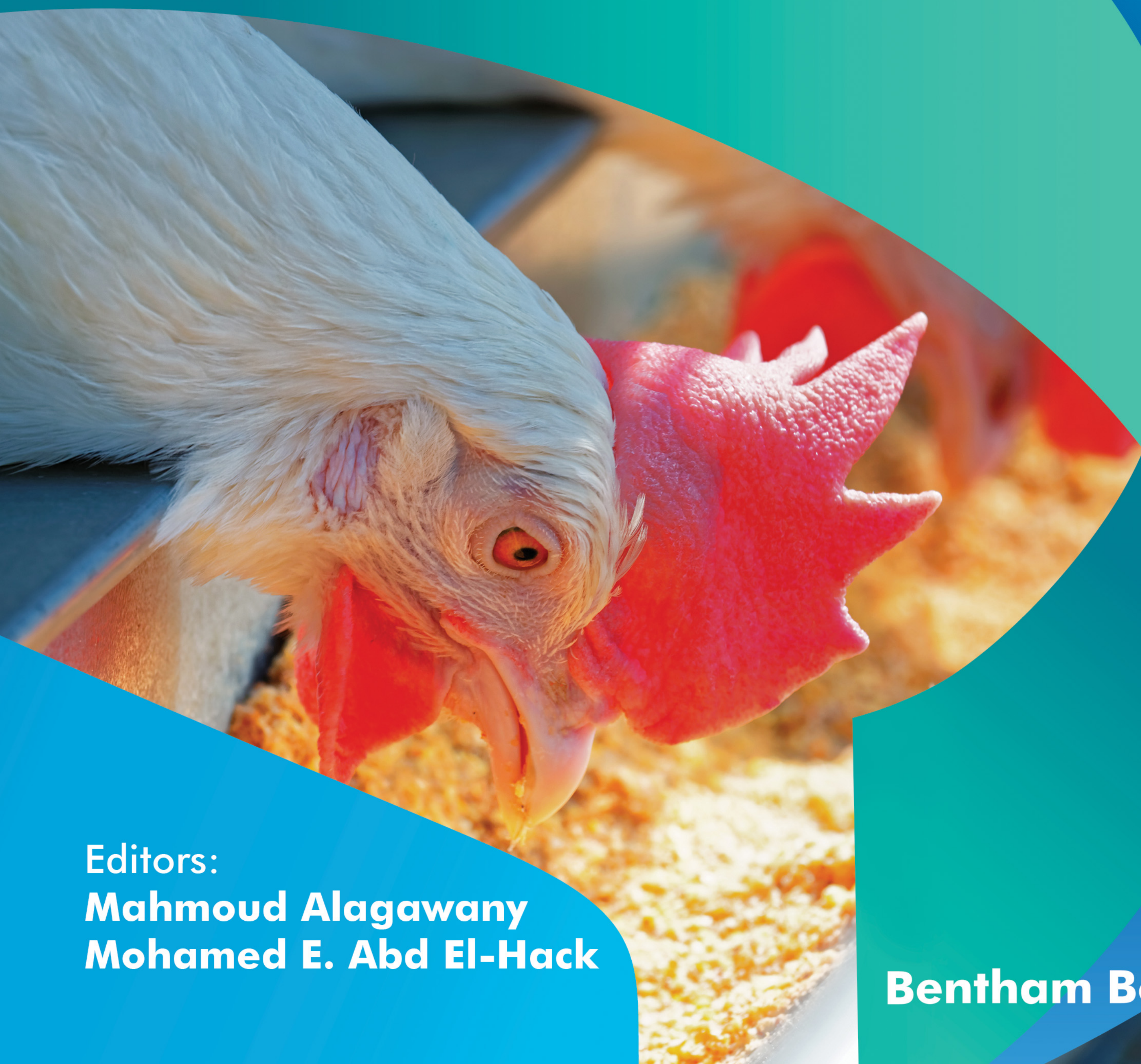
Natural Feed Additives Used in the Poultry Industry



Editors:
Mahmoud Alagawany
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Natural Feed Additives Used in the Poultry Industry

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FOREWORD

I was delighted when I received a request from Mahmoud Alagawany and Mohamed E. Abd El-Hack to write a brief foreword to the reprint of this book because, for several years, I have admired their incredible work. Moreover, as a consumer of poultry products, I always search the markets for organic products to keep my body away from the antibiotic residues. So, I believe that the topic of this book is much needed for all people who produce or consume poultry products in their food.

Looking through this magnificent book, I am amazed at the authors' talent and what they achieved with a pencil. It is more than a book of lovely illustrations. It is a mine of information, demonstrating their technique in the minutest detail and it is a source of inspiration and information for those who work in the poultry production field.

In shorts, Alagawany and Abd El-Hack's book is unique and indeed work to treasure for anyone interested in poultry production. So, read it, enjoy it and learn from it. Thank you, Alagawany and Abd El-Hack, for producing such a masterwork.

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PREFACE

Feed additives are non-nutritive preparations and formulations as well as useful microorganisms that are added to animal diets to enhance the growth, production, feed utilization, nutrient digestibility and absorption, immunity, public health, *etc*. This book on Natural Feed Additives Used in the Poultry Industry addresses recent information on the use of different natural feed additives in poultry nutrition with regard to growth, production and reproduction and health of poultry. This book contains 16 chapters contributed by 38 experts and scientists of animal and poultry nutrition, animal and poultry physiology, toxicology, pharmacology, and pathology, which highlights the significance of herbal plants and their extracts and derivatives, cold pressed and essential oils, fruits by-products, immunomodulators, organic acids, probiotics, nanoparticles and their role in poultry industry instead of the growth promoter antibiotics. This book provides details about the use of antibiotics as growth promoters in the poultry industry and the development of bacteria resistance to antibiotics. All chapters provide a holistic approach to how natural feed additives can provide an efficient solution to animal health, also covering the main categories of poultry, including broiler chickens, laying hens, quails, geese, ducks, and turkey. This book represents an up-to-date review of the existing knowledge on natural feed additives, both *in vitro* and *in vivo* and the basis for future research. This book is useful to the students of poultry sciences, nutritionists, scientists, veterinarians, pharmacologists, poultry breeders, and animal husbandry extension workers.

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CHAPTER 1

An Overview of Natural Feed Additive Alternatives to AGPs

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Improving the growth rate and preventing infectious diseases of food-producing animals, including poultry, are critically required to satisfy the dietary needs of the growing population around the world. Antibiotics are drugs of low or medium molecular weights with variable biological and chemical characteristics. They could be produced naturally from microorganisms or synthesized in the laboratories. Antibiotics have been used extensively in the poultry sector for therapeutic purposes such as treatment and prevention of infectious diseases and reduction of their incidence by inhibiting the growth of microorganisms or destroying them to improve the bird's health. They also have been applied in sub-therapeutic levels as feed additives to promote the rates of growth, improve weight gain, enhance feed efficiency and increase egg production to provide adequate amounts of eggs and meat of good quality needed by consumers at reasonable costs. Anyway, the extensive use of such antibiotics in poultry diets raised concerns about increasing the incidence of resistant pathogens, which has an adverse effect not only on poultry performance but also on the health of humans.

In the last years, several substances have been used as good alternatives to antibiotic growth enhancers. Herbal plants and its derivatives (extracts, cold-pressed oils and essential oils), probiotics, fruits by-products, organic acids, nanomaterials, blends of such phytogenic feed additives have been accepted as suitable alternatives with distinct mechanisms. The beneficial uses of natural herbal plants in medical sciences have achieved great attention due to promising health benefits in comparison with synthetic pharmaceutics.

Due to its nutritional and immunological effects, such as improved feed efficiency, regulation of endogenous digestive enzymes, efficiency, regulation of endogenous digestive enzymes, immune response stimulation, antiviral, antibacterial, efficiency, regulation of endogenous digestive enzymes, efficiency,

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regulation of endogenous digestive enzymes, immune response stimulation, antiviral, antibacterial, and antioxidant properties, medicinal plants seem to be of great importance.

Improving poultry production using probiotics as feed additives is one of the decent alternative options to antibiotics. Probiotics are described as "living microorganisms that confer a benefit on the host health when applied in adequate quantities". Probiotics as feed additives help in feed digestion by creating the nutrients in an available form for growing faster. Also, supplemented poultry diets with probiotics improved immunity status. Besides, fortified poultry diets with probiotics enhancing meat characterization and egg quality traits; while selected natural feed additives such as whole herbal plants, cold-pressed oil, essential oils proved to be able to reduce oxidative stress and inflammation in poultry, enhancing the digestibility of nutrient.

Also, organic acids are used as natural preservatives for food products and as hygiene promoters that affected microbial growth, which improved the freshness and shelf-life of food items. This book describes the benefits and the hazards of using antibiotics as growth promoters in poultry feeding and also discusses the valuable effects of natural feed additives on poultry production and health and their critical role in the poultry industry.

CHAPTER 2

Antibiotics as Growth Promoters in Poultry Feeding

Mayada R. Farag[1,*], **Mahmoud Alagawany**[2,*], **Mohamed E. Abd El-Hack**[2], **Shaaban S. Elnesr**[3], **Gihan G. Moustafa**[1], **Kuldeep Dhama**[4] and **Nabela I. El-Sharkawy**[1]

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Abstract: The improvement in the growth of birds through the use of antibiotics could be obtained by reducing the count of harmful microorganisms, providing beneficial ones by suitable growth media, decreasing the thickness of gut mucosa and regulating the motility of gut, leading to better absorption of nutrients. However, achieving these desirable goals is not devoid of risks. Where, the frequent and improper use of antibiotics can reverse their therapeutic advantages through giving the opportunity to any existent microorganism to develop antibiotic resistance, which can hinder the effectiveness of antibiotics as chemotherapeutic or prophylactic agents in poultry. Additionally, antibiotic resistance genes can be transmitted to the natural environment and contaminate soil, water and plants. Moreover, the indiscriminate application of antibiotics could result in the accumulation of noticeable amounts of drug residues (the parent compounds or their injurious metabolites) in the edible tissues of poultry, including eggs and meat, which are very important sources in human feeding. The residues of antibiotics in poultry products can result in various pathological conditions and hazardous impacts on human health, such as being sensitive to antimicrobials in addition to allergy, cell mutations, imbalanced microbiota in the intestine and the development of bacteria resistance to antibiotics. This chapter describes the benefits and the hazards of using antibiotics as growth promoters in poultry feeding.

Keywords: Antibiotics, Feed additives, Growth promoters, Poultry.

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Mahmoud Alagawany & Mohamed E. Abd El-Hack (Eds.)

INTRODUCTION

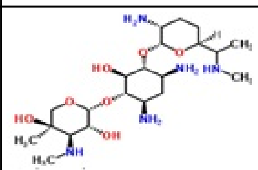
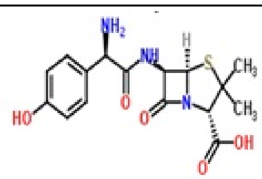
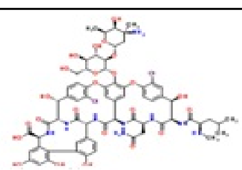
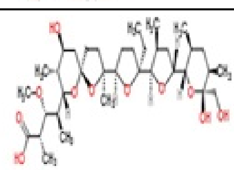
Antibiotics are among the most essential veterinary drugs associated with animal and poultry production as they could inhibit the growth of microorganisms or destroy them when used at low levels without damaging the host [1]. The antibiotics are used in the poultry industry for treatment (therapeutic) and prevention (prophylaxis) of diseases, modifying the body physiology, and for growth-promoting purposes [2]. The growth-promoting properties of antibiotics were first observed by Moore *et al*. [3]. They reported that birds exposed to streptomycin in their diet showed improved growth response. Some other experiments followed this study in chickens and different animal species with similar results [4 - 7]. Since then, the use of antibiotics as growth promoters became one of the most common well-established practices in the livestock industry and increased with animal production intensification. Antibiotics are utilized in poultry diet as feed additives to improve the growth, feed efficiency and productivity and to ensure food safety [8 - 10]. However, reaching these desirable objectives is related to some risks, where the inappropriate handling and use of these antibiotics have led to the accumulation of noticeable concentrations of harmful residues in edible poultry tissues and eggs [11]. Consumption of these residues can lead to various health problems and the development of antibiotic resistance in pathogens and/or commensal microorganisms, which may result in severe pathological conditions and consequently threaten the public health [12]. However, the transfer of antimicrobial resistance genes from animals to human pathogens is still unconfirmed. Several works showed a relationship between the improper use of antibiotics at sub-therapeutic levels and the development of antibiotic resistance in microflora [13 - 17].

Therefore, the antibiotic-treated birds should be held for specific withdrawal periods for the depletion of the antibiotic residues to safe levels in eggs and tissues. Moreover, applicable and straightforward screening methods should be developed for the detection of antimicrobial residues in edible tissues before reaching consumers [18]. Additionally, it is important to search for antibiotic alternatives such as probiotics, prebiotics, synbiotics, phytogenics and others to increase birds' productivity and help them perform their genetic potentials under commercial conditions [19]. The main objectives of the following sections are to provide an overview on the use of antibiotics as growth promoters in poultry production and to review the public health risks related to the residues of antibiotics (human health effects, antimicrobial resistance) and the techniques of their screening and detection in food from animal origins. Lastly, this chapter highlights the measures and recommendations to control or prevent antimicrobial residues in poultry tissues.

TYPES AND PROPERTIES OF ANTIBIOTICS

Antibiotics are all bacteriostatic, which could prevent the growth and division of the bacterial cell. Some of them can be bacteriocidal or even caused bacteriolysis. Antibiotics can exert their mode of actions through direct or indirect prevention of nucleic acid replication, interfering with protein development required for the growth of bacteria or interfering with the synthesis of the cell wall [20, 21]. The mechanism of the antimicrobial action of antibiotics is illustrated in Fig. (**1**). The most common types of antibiotics (aminoglycosides, beta-lactam antibiotics, tetracycline, polypeptide antibiotics, sulphonamides, quinolones, chloramphenicol, and macrolide antibiotics), their action mechanisms, the spectrum of activity and some specific characteristics are represented in Table **1** as extracted from Diaz-Sanchez *et al*. [22].

Table 1. Classes of antibiotics and their mechanisms of antimicrobial action, activity spectrum and some specific characters.

Class	Structure	Source	Action	Activity Spectrum	Characters
Aminoglycosides		Streptomyces spp.	Inhibit the synthesis of protein	Gram-negative	Form strong and irreversible bond with the ribosome by which they could inhibit bacterial re-growth.
Beta-Lactams		Fungal product	Inhibit the synthesis of cell wall	Gram-negative and some Gram-positive	Unstable in acidic media. Various bacterial strains secrete lactamases, which could break the cyclic bond in Beta-lactams chemical structure.
Glycopeptides		Chemically synthesized	Inhibit synthesis of peptidoglycan (act on cell wall or membrane)	Gram-positive enterococci	Restricted for use in food animals.
Polyether ionophores		Chemically synthesized	Increase the cell membrane leakage	Parasitic coccidia	Some of them are converted to inorganic arsenic by bacteria present in the liter.

CHAPTER 3

The Role of Garlic and Rosemary Herbs in Poultry Nutrition

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Abstract: The use of herbal plants as natural remedies is gaining immense global popularity in feeding systems of humans and animals including avian species due to their promising health benefits. Among the livestock sector, poultry production and regulations are in a continuous development, particularly in the field of nutrition, genetic, refinement, management and disease prevention, which could be probably achieved through regulation of the nutritional needs and the poultry production prerequisites. Therefore, this section is directed toward the use of herbs as a therapeutic and sustainable production tool, because of their health and economic benefits. This chapter will discuss and highlight the valuable impacts and the latest features of supplementing the livestock rations with garlic and rosemary herbs, including their promising natural growth promoting activities and useful applications in improving, performance, feed efficiency and nutrient digestibility in addition to enhancing antioxidant capacity and immunological responses and this would be helpful for veterinarians, scientists, pharmacists, physiologists, pharmaceutical industries, nutritionists and poultry breeders.

Keywords: Beneficial effects, Garlic and rosemary, Mechanism of action, Poultry, Sources.

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INTRODUCTION

Several medicinal plants can be considered as potential feed additives resources in poultry production due to the presence of phytochemicals with powerful antioxidant properties [1 - 4]. Garlic (*Allium sativum* L.) is a perennial herb with a pear which is divided into segments or cloves and is commonly used as medicinal plant in all regions of the world to prevent and treat a broad class of diseases extending from infection to heart diseases (Fig. **1**). Garlic is believed to be among the 20 main vegetables, with different uses globally. It is being used as a crude vegetable intended for cooking or eating or as a constituent of many modern herbal and other chemical-based drugs. Also, it is suggested as a very unique and one of the wealthiest resources of total phenolic contents in the diet of human beings [5]. Recently, multiple investigations have proved the notable biological roles of garlic, such as anticancer, antioxidant, cardioprotective, immuno modulatory, anti-inflammatory anti-bacterial, antifungal anti-diabetic and anti-obesity properties [6 - 11]. Garlic has also been acknowledged as broiler supplement due to its role in improving the digestion and immune response of birds [12]. These characteristics were ascribed to the bioactive elements in garlic, such as allicin, diallyldisulphide and alliine with antibacterial and antioxidant activities [13 - 15]. Moreover, the lipo-soluble garlic organosulfur components, for example, n-acetyl cysteine or S-ethyl cysteine and diallyldisulphide have been reported to reduce lipid oxidation levels [16].

Fig. (1). Garlic plant.

Rosemary (*Rosmarinus officinalis* L.) is a member of the family *Lamiaceae* (Fig. **2**) which is associated with the Mediterranean countries. The plant has pink, purple, white or blue flowers and is currently spreading globally due to its medical and industrial uses [17].

Fig. (2). Rosemary plant.

Since ancient times, rosemary has been used as a drug to treat the kidneys and dysmenorrhea. Moreover, it has also been used to relieve signs of breathing and lung-related sicknesses/problems. Moreover, the extracts of rosemary are used to treat anxiety and stress [18]. In today's scenario, several herbal extracts and essential oils have become a great point of interest because of their possible applications as an alternative to different drugs [19]. Rosemary oil has also been shown to improve meat production as well as egg quality traits [20 - 22]. Rosemary products may inhibit oxidative damage and bring blood cholesterol contents in a normal range. Carnosol, carnosic acid and esters are the principal biologically active constituents of rosemary oil [23]. Data from various studies indicated that carnosine acid, a valuable phenolic components in rosemary oil can serve as antioxidants as tocopherol [21], and showed a higher antioxidant activity than some synthetic antioxidants [24]. This chapter describes the beneficial applications and new aspects of garlic and rosemary herbs, including its useful applications, health benefits.

CHAPTER 4

Nigella sativa Seeds and their Derivatives in Poultry Feed

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Abstract: The addition of antibiotics to poultry diets caused many cases of antibiotic residues and a large number of pathogens that are resistant to drugs. So there was an urgent need to use alternative medicine. Many studies have assured that *Nigella sativa* (black cumin) seeds might be an adequate replacement for standard therapeutic procedures like antibiotics in poultry. *Nigella sativa* plays a significant role in promoting the bird's health and productivity, besides acting as a natural immuno-stimulant and antioxidant. The black seed oil contains high amounts of polyunsaturated fatty acids, and in this way, it lowers the total cholesterol content. Due to the high content of bioactive compounds, black cumin is proven to have anticancer effects. The present paper enumerates the natural benefits of *Nigella sativa* on nutritional and health aspects for poultry.

Keywords: Health, *Nigella sativa*, Poultry, Production, Seeds.

INTRODUCTION

Antibiotics and other food supplements have been used in large amounts for a long time in the poultry industry. Fortunately, the global awareness about antibiotic residues and diseases that are related to the resistance to antibiotics has risen [1 - 3]. Banning of antibiotics as dietary additives resulted in increased usage of various supplements, which has resulted in more studies regarding animal production using natural additives [4, 5].

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Aromatic herbs and their extracts could be such additives, like rosemary, thyme, and *Yucca schidigera* [6 - 8]. The seed of black cumin, which comes from the family of *Ranunculacease,* belongs to the herbs that could be used for such purpose. It is known under many names, like black cumin, black caraway, habbatul barakah, Qazhe shuniz, and probably some other. Black cumin is an herb that has been used as a therapeutic for over 2000 years for various diseases. It has also been mentioned in prophetic medicine, which has been practiced by the **Prophet Mohammad [PBUH].**

Furthermore, Abu Hurayrah [RA] PBUH narrated "use black seed regularly because it is a cure for every disease, except death [9, 10]. Moreover, the Holy Bible characterized the black seed as the curative "black cumin", Hippocrates and Dioscorides interpreted this herb as Melanthion, while Gith described it as Pliny [11]. This herb originates from Asia, South Europe, East Mediterranean, and is cultivated, especially in Turkey [12]. Regarding the composition, black cumin seed contains proteins [210 g kg^{-1}], oil [350-380 g kg^{-1}], and carbohydrates [g kg^{-1}]. One thousand seeds averagely weigh about 2-3 g. Seed efficiency alters between 75-150 kg/day, depending on various factors, like soil, climate, and cultivation conditions [12]. The primary purpose of black cumin seeds is medical, but it is also used as spice and supplement in food [13]. Lately, researchers determined that the black cumin seed has various positive effects in the organism, such as antibacterial, bronchodilatation, regulating blood pressure, and stimulating the bile flow. The goal of this chapter is to accentuate the significance of *Nigella sativa* seeds in poultry nutrition, as well as to give information on the pharmaceutical effects of this herb.

MORPHOLOGY OF *NIGELLA SATIVA* AND CHEMICAL COMPOSITION

Black cumin is an annual plant, height approximately 45 cm and 2-4 cm on average, with 2-3 narrow pinnatisect leaves (Fig. **1**). It has relatively blue flowers on long single pedicles. The seeds have a triangular cross-section and are black. With a rather stiff and branching stem, the black cumin plant has greyish-blue flowers and greyish-green leaves. Its small and compressed seeds, which mostly have three corners, are found in seed vessels, usually found in odd numbers. The seed vessels of black cumin have two flat sides and one convex side, and they are black or brown and have a strong odor, very aromatic – like the odor of nutmegs, while its taste is very spicy. *Nigella sativa* usually has blue and white flowers, with several petals in the range 5-10. Its fruit can be described as a large capsule, fairly inflated, and it contains single follicles [mostly 3-7] that provide a great amount of seed. It has a sharp and bitter taste, a faint strawberry aroma [14].

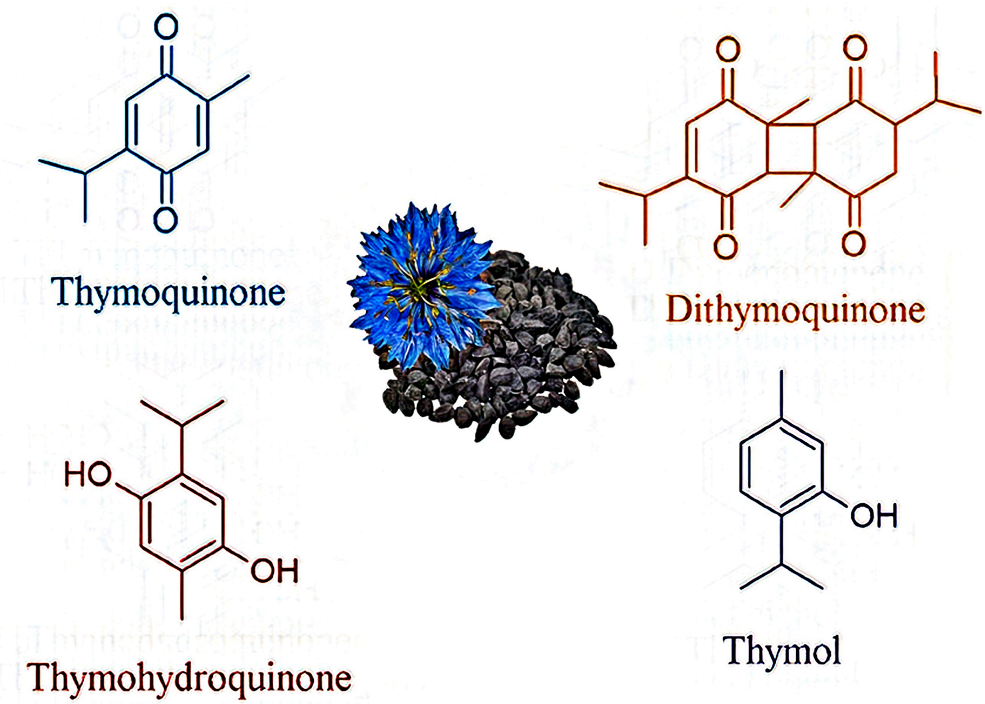

Fig. (1). Active chemical constituents in *Nigella sativa*.

PHARMACEUTICAL ACTIVITIES OF *NIGELLA SATIVA*

Antioxidant Effects

In streptozotocin-induced diabetic rats [60 mg/kg], the black cumin extracts proved to have a protective effect against oxidative stress [15]. Dietary concentrations of *Nigella sativa* [200 mg/kg] magnified the intensity of thiol in the hippocampus, in comparison to the control group of rats [15]. While using extracts of *Nigella sativa*, malondialdehyde [MDA] concentrations decreased in the hippocampus [200, 400 mg/kg] of diabetic rats compared to the control group [15]. Abbasnezhad *et al*. [15] showed that the black cumin applied to rats [200 mg/kg] had beneficial outcomes in minimizing oxidative stress in the hippocampus. Hosseinzadeh *et al*. [16] conducted a study, where they first inducted ischemia and afterward injected intraperitoneally the extract of *Nigella sativa* [0.048, 0.192 and 0.384 mg/kg] every 24 hours to 72 hours, which led to a significant decrease in levels of MDA in comparison to the ischemic group. Vafaee *et al*. [17] studied the remedial effects of the hydroalcoholic black cumin

CHAPTER 5

Beneficial Impacts of Licorice (*Glycyrrhiza glabra*) Herb to Promote Poultry Health and Production

Mohamed E. Abd El-Hack[1,*], **Sameh A. Abdelnour**[2], **Asmaa F. Khafaga**[3], **Ayman A. Swelum**[4] and **Mahmoud Alagawany**[1,*]

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Abstract: Supplementations of livestock diets with herbs that have many active constituents revealed favourable effects as natural feed additives. These compounds could stimulate nutrient digestion, growth performance, food utilization, enhance immunological sides and antioxidant status and decrease health disorders. Various previous reports have employed mixture formulas of herbal with partial enclosure of licorice. However, the data about using licorice independently is very scared. The poultry industry faces many epidemiological syndromes; principally, those are confined to digestive, respiratory and immune system syndromes. Flavonoids and glycyrrhizin are the main bioactive components in Licorice. The roots of this herb contain 1-9% glycyrrhizin, which has several pharmacological actions such as anti-oxidant, antimicrobial, anti-heat stress, and anti-infective antiviral and anti-inflammatory activities. Licorice extracts (LE) have affirmative impacts on the management of high incidence ailments, such as the immune system, lung, and liver disease. Licochalcone A (2-8μg/mL) inhibits cancer cell proliferation by reducing DNA synthesis in these cells . Moreover, the hepatoprotective effect of LE (100-300 mg) against CCI_4-induced hepatic injury in rats has been observed. Studies suggested the potential role of LE (0.1, 0.2, or 0.3 g/L of drinking water) in reducing serum total cholesterol of broiler chicken significantly. Also, the presence of licorice root extract (0.1 g/d) in the patient diet for 1 mo led to a decrease in plasma triglyceride (by about 14%) and cholesterol (by about 5%) levels.

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Moreover, dietary supplementation of LE plays a substantial role in the productive performance of poultry owing to the improvement of organ development and stimulating influence on digestion and appetite. Along with its growth promoting properties, licorice has antioxidant, detoxifying, anti-inflammatory, antimicrobial, and many more health benefits as enclosed in the current chapter. This chapter highlights the favourable applications and modern features of *Glycyrrhiza glabra* (licorice) herb, including its chemical composition and maintenance of the health status of poultry. Hence, it will be highly useful for nutritionists, physiologists, pharmacists, veterinarians, and poultry producers.

Keywords: Health, Licorice, Pharmacological, Poultry, Production.

INTRODUCTION

Herbs have gained great attention for their many favorable uses in humans and animal studies, and their importance is realized over the world [1]. Nowadays, the addition of feed additives and nutritional supplements in diets of birds, including growth promoters, nutraceuticals, herbs, and probiotics, is gaining significant attention due to their multiple constructive practices while improving the production and growth performances as well as maintaining the health status of poultry [2 - 7]. This chapter is focusing on one such medicinal plant known as licorice (*Glycyrrhiza glabra*). Licorice, a common medicinal plant that belongs to the legume family (Fabaceae), has been widely employed in traditional medicine for more than thousands of years [8, 9]. Not only humans consume licorice, but it is also the most extensively used herb in animal and poultry diet [10]. It is mainly employed as a food preservative agent, for commercial purposes and in the medicine sector [11]. It is derived from the sweet root of different kinds of Glycyrrhiza; however, cultivation and harvesting pursuits alter the ingredients of different biologically significant constituents of the *Glycyrrhiza* plant [12, 13]. Licorice appears a replacement candidate, described as beneficial for its antimicrobial, radical scavenging, antiatherosclerotic, antioxidative, anti-inflammatory, and antifungal estrogen-like, antiviral, anti-infective, and antinephritic activities [14].

Considering phytochemical screening, the main fraction of licorice extract (LE) contains flavonoids (*e.g.*, liquidity, isoflavonoids and formononetin), and triterpene saponins (*e.g.*, glycyrrhizin, glycyrrhetinic acid and licorice acid), phytosterols, coumarins, amino acids, choline, sugars, starch, ascorbic acid and some other bitter principles [15]. Notably, many pharmacological impacts have been termed for LE and its derived bioactive components in animals. Liquorice lollipops were found effective in reducing *S. mutans* counts from dental caries cases in children [16, 17] and recommended to be used as growth promoters in poultry diet as a supplement. Therefore, the extracts are used as a remedy for the treatment of different ailments and disorders such as hypocortisolism, bronchitis, cough, arthritis, rheumatism, hypoglycemia, dental caries, inflammatory and allergic conditions, gastric ulcer, and chronic hepatitis B and C [18, 19].

Aoki *et al*. [20] concluded a significant decrease in body weight gain and abdominal fat pad with an increase in lean body mass as a physiological effect of LFO inclusion in mice diet (1 & 2%, for eight weeks) that stimulates lipid breakdown in adipocytes; these findings have been confirmed in another study conducted by Armanini *et al*. [21], where they concluded significant decrease in body fat mass (from 12.0 to 10.8 in male, and from 24. 9 to 22.1 in female) after 2 months of dietary inclusion of 3.5 g a day of licorice, several studies confirmed similar finding later [22, 23].

This chapter defines the beneficial uses and modern features of licorice herb containing chemical components, valuable applications, health welfares, which will be extremely convenient for nutritionists, pharmacists, scientists, poultry breeders, veterinarians, and pharmaceutical industries. So, we can end up with a safe validation and get a new apparition to promote the exploration of licorice profits in the poultry industry.

CHEMICAL COMPOSITION AND STRUCTURE

Liquorice is also identified as Liquiritiae radix or Radix Glycyrrhizae. It is the root part of *Glycyrrhiza glabra* L., or *Glycyrrhiza uralensis* Fisch or *Glycyrrhiza inflate* Bat., Leguminosae [24]. Roots of *Glycyrrhiza glabra* are broadly employed in preparing numerous pharmaceutical purposes (Fig. **1**).

Based on that, phytochemical inquiry of licorice root extract revealed that it comprises flavonoids (formononetin, liquiritin and isoflavonoids), saponin triterpenes (liquirtic acid and glycyrrhizin), and other bioactive constituents such as tannins, phytosterols, coumarins, sugars, starch, amino acids, and vitamins as ascorbic acid [15, 25 - 28]. Documents showed that more than 300 flavonoids and 20 triterpenoids had been screened in licorice [29]. As per literature, *Glycyrrhizae radix et rhizoma* is broadly used in traditional Chinese medicine for curing various diseases. However, the bioavailability of various components after absorption from the intestinal tract varies. Due to transformation within the body, some structural modifications occur, which affect their uptake through the cells within the body. This variation in absorption has been deliberated using the human Caco-2 monolayer cell line model to assess the intestinal absorption of flavonoids and triterpenoids obtained from Glycyrrhizae radix rhizoma plant as it can alter the oral dosage of various components used in clinical applications or as nutritional supplements. Results projected that licochalcone B, licochalcone C,

CHAPTER 6

The Useful Applications of *Origanum Vulgare* in Poultry Nutrition

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Abstract: *Origanum Vulgare* (OV) is a member of the family Lamiaceae which grows naturally in the Mediterranean area. It is a less toxic, residue-free and standard natural feed additive for poultry. There were many promoting characteristics of oregano dependent on its bioactive constituents as carvacrol and thymol. It possesses many properties, including antimicrobial, antiviral, antioxidant, antiparasitic and immunomodulatory. The possible benefits of utilizing OV in the poultry sector include enhancement of the growth, feed utilization, feed efficiency and improvement of the absorption and digestion and consequently a better productive performance. On the other hand, OV can reduce the disease occurrence and economic losses. The inclusion of oregano essential oil [OEO] in broiler diets at levels of 0.6-1% enhanced the growth performance and reduced the mortality in the broiler herds. Remarkable enhancement on the intestinal microbiota, fewer fermentation products andenhanced intestinal mucus synthesis and intestinal cell functionality have been observed by 15 mg/kg of OEO, reflecting a whole better intestinal equilibrium in poultry. Dietary supplementation of OEO at 300-ppm displayed higher IgG titers and enhanced the immune responses in the broiler. Bioactive ingredients isolated from OV could be employed in poultry feeding. To acheive the best productivity of poultry, oregano feed supplements should be used as an alternative to antibiotics and drugs due to the absence of side effects and residual impacts. The present chapter provides evidence on the usage of OV and its products in poultry feeding besides their application as feed additives in the poultry industry.

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Keywords: Antioxidant, Health, Immunity, *Origanum vulgare*, Performance, Poultry.

INTRODUCTION

The inclusion of phytogenic feed additives may have several positive effects on poultry production. Generally, they could regulate the intestinal functions and improve the growth performances of birds in addition to supporting the general health of the animal and improving the storage safety and meat measurements [1, 2]. *Origanum vulgare* L. (OV) from Lamiaceae family is an aromatic herb, which grows easily in Mediterranean countries [3]. The pharmacodynamics properties of the OV extract may be due to its active components such as carvacrol and thymol which act synergistically as broad-spectrum antimicrobial (bactericidal, fungicidal, and viricidal), antispasmodic, antiparasitic, diuretic, stomachic and immunomodulation agent.

The previously declared results on the usefulness of the dietary application of OV and its extracts or essential oils as growth promoters are deliberated in the present chapter. However, the impacts of OV addition to poultry diets on some hematological variables are very rare [4]. In this chapter, we have described the chemical structure and ingredients, biological activities and favorable uses of OV in feeding and its impacts on health features of poultry. The evidence offered in this chapter would be valuable for the nutritionists, scientists, researchers, veterinarians, students, pharmacists and medical professionals and poultry producers.

SCIENTIFIC CLASSIFICATION AND ANATOMICAL STRUCTURE

The basic components of *Origanum vulgare* are presented in Fig. (**1**).

Biological Activities and Beneficial Aspects in Poultry

Enhanced Intestinal Functions, Growth Rate and Productivity

Natural feed additives have shown favorable impacts on intestinal functions, gastrointestinal cell wall, and whole productivity of birds, meat measurements and storage safety. Abdo *et al.* [5] studied the impacts of marjoram [1.5 and 3%] on broiler performance. Authors showed that marjoram at 1.5% gave the best body weight (BW) and body weight gain (BWG). Besides, Ali [6] evaluated the influences of three levels of marjoram [0.5, 1.0 and 1.5%] on the performance of broiler chicks. The author reported that supplementing the broiler diet with marjoram improved BW and BWG at 6 weeks of age. Moreover, the oregano

[15mg/kg diet] can make a noticeable enhancement on the ileal villus height and intestinal microbiota of broilers when mixed with attapulgite [2.4 g/kg diet] [7].

Also, Bozkurt *et al.* [8] assessed the influences of oregano essential oil (OEO) at the level of 1000 mg/kg diet, on the broilers performance, and they concluded that BWG was significantly improved at 3-6 weeks of age compared to the control group (no antibiotic of prebiotic feed additives). Additionally, a study conducted by Fotea *et al.* [9] showed better BWG with a diet containing 1% of the oregano oil. Moreover, BWG was improved significantly by the inclusion of OEO at a level of 0.6g/kg in the broiler diet compared with the unsupplemented group. Ghazi *et al.* [10] stated that feeding broiler with diet with OEO [250 mg/kg diet] improved BW and BWG compared with those in the control group. The addition of 0.005 and 0.010% of OEO enhanced the BWG in broiler chickens. While, at the marketing age, the upper dosage of OEO acheived the maximum BWG.

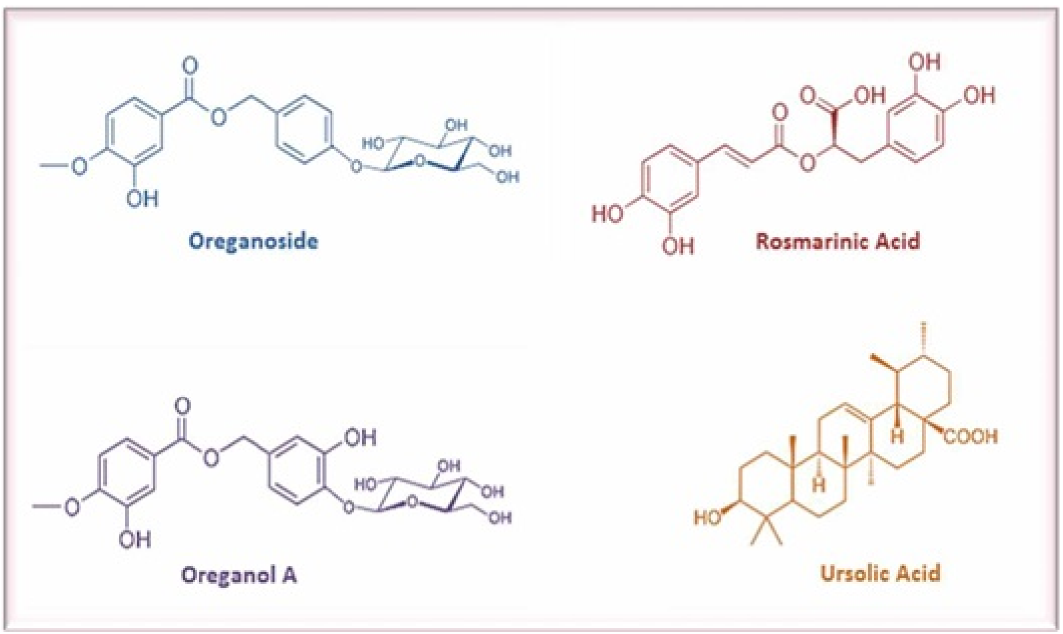

Fig. (1). The composition of the dried leaves of oregano.

Furthermore, several studies indicated that the inclusion of oregano oil [300ppm] in the poultry feed significantly enhanced the intestinal microbiota function [11, 12]. Broilers received a 0.3g/Kg diet of OEO which exhibited higher daily BWG compared with those receiving a higher level of OEO [0.5g/kg diet] or no treated group [4]. Badiri and Saber [13] recorded the effect of different levels of OEO [0, 50, 100, 200 and 400 mg/kg] on the growth criteria of Japanese quail. The consequences advised that the BW and BWG were noticeably augmented in the

CHAPTER 7

Importance of Quinoa (*Chenopodium Quinoa*) in Poultry Nutrition

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Abstract: Quinoa is a grain-like food crop with a higher nutritional value compared to other cereals. It has been reported to be an excellent source of fiber, protein, lipids, minerals, amino acids and vitamins. Quinoa represents a good source of fiber (10%), which is much higher than that of wheat 2.7%, corn 1.7%, and rice 0.4%. The quinoa seed comprises protein (120-180 g/kg), which contains a better-balanced amino acid composition than conventional crops such as cereals. Quinoa also contains several beneficial health compounds, including phytoecdysteroids, phytosterols, saponins, betalains, glycine and phenolics. Dietary supplementation of quinoa has shown significant effects on growth performance, public health and production performance of large and small animals. Birds fed diets supplemented with quinoa at a low level (50 g/kg) had achieved a better performance without any adverse effects. But the high level (150 g/kg diet) of quinoa reduced live body weight at 20 days of age from 627 to 601 g and at 39 days of age from 1760 to 1709 g, respectively, while feed conversion ratio was increased from 1437 to 1486 g feed kg^{-1} live body weight at 20 days of age. Birds fed a diet enriched with 30 g/100 Kg recorded higher body weight and feed intake compared to those fed on 10 g/100 Kg and the control group. Supplementation of 40 or 80 mg/kg of iso-flavones increased total antioxidant capacity in the blood of chickens.Hitherto, there is a gap in the knowledge base of quinoa as a feed additive, which is not widely considered in poultry feeds.

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Thus, this chapter aims to find the medicinal and nutritional importance of quinoa to boost the performance and health in poultry farming.

Keywords: Anti-oxidant, Feed additive, Health benefits, Poultry, Quinoa.

INTRODUCTION

Quinoa (*Chenopodium quinoa*) is one of the most famous medicinal plants that belong to the Chenopodiaceae family and was originally found in the Andean region in South America region. Quinoa has a broadleaf and its seeds are used as cereal-based foods. The seeds of quinoa crops have been known as pseudo-cereal gluten-free grains. They have gained attention in recent decades because of their extraordinary nutritional value and potential health benefits. The Food and Agriculture Organization of the United Nations (FAO) pays great attention to the promotion of planting, research and development on quinoa. Quinoa is cultivated in most of the world's arable regions and can adapt to the tropical climate under various harsh environmental conditions. Also, it is being used in foods and for pharmaceutical purposes [1].

The grain of this plant has been recognized as a rich source of good quality macro- and micro-nutrients such as proteins, carbohydrates, vitamins, fat and minerals, as compared to other cereal grains such as wheat, oats, maize and rice [2, 3]. Additionally, seeds of this plant are rich in vitamins such as vitamins B, C and E [4]. Biological compounds such as betanins, terpenoids, and phenolic compounds and their potential health benefits have been shown in many studies [5, 6]. The bioactive phytochemical compounds of quinoa grain have exhibited various therapeutic effects like anti-oxidant, anti-inflammatory, immuno-modulation and other health-promoting effects based on different *in vitro* and *in vivo* studies [1]. It should be pointed out that the mechanisms of action of these bioactive compounds individually or collectively contribute to the overall nutritional value, especially to the health benefits, which have not yet been fully explored. Commercial poultry farming derives its daily energy from cereal-based foods. Quinoa is a grain-like food that can provide nutrition and sustenance to animals and has recently attracted more attention in poultry diets. Previously published studies have proven several functions of quinoa seeds in livestock and poultry due to their high nutritional value, numerous biological activities and health benefits. The available literature regarding the use of quinoa seeds as a functional food and therapeutic application in poultry feed is relatively scarce. However, additional scientific investigations are needed to recognize further and promote the role of quinoa in the production performance of the poultry industry. Therefore, the aim of this chapter is to explore the medicinal and nutritional importance of quinoa as a feed additive to boost both productivity and health performance in poultry farming. Another objective of this reappraisal is to highlight the most recent advances in the phytochemical compounds of quinoa and their contribution to the pharmacological aspects and potential health benefits of poultry.

NUTRITIONAL AND PHYTOCHEMICAL COMPOSITION OF THE QUINOA PLANT

The biological value and nutritional composition of quinoa and its grains have been estimated in many studies (Tables **1**, **2**, **3** and **4**). This plant has been characterized as a notable source of both α and γ-tocopherol, folic acid, riboflavin and thiamine. In comparison with other grains, it includes high concentrations of copper, magnesium, iron, calcium, potassium, zinc and phosphorus [7, 8]. It has also been reported as an important source of micronutrients such as protein, lipids, essential amino acids such as (cysteine, lysine and methionine), minerals (copper, calcium, manganese, iron and zinc) and vitamins (thiamine, riboflavin, niacin, folic acid and retinol) in addition to significant amounts of other bioactive components with health-promoting impacts, like phytosterols, flavonoids and polyphenols [9 - 11].

Table 1. Nutrient content of Quinoa.

Nutrient	**Unit**	**Value Per 100 G**
Proximal		
Water	g	13.28
Energy	kcal	368
Energy	kJ	1539
Protein	g	14.12
Total lipids (fat)	g	6.07
Ashes	g	2.38
Carbohydrates, by difference	g	64.16
Fibre, total dietary	g	7
Starch	g	52.22
Minerals		
Calcium, Ca	mg	47
Iron, Fe	mg	4.57
Magnesium,	Mg	197
Phosphorus,	P mg	457
Potassium, K	mg	563

CHAPTER 8

Turmeric (*Curcuma longa*) as a Useful Feed Supplement in Poultry

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Abstract: In the last decade, poultry nutritionists were particularly interested in inspecting relevant natural antibiotic alternatives to be used in poultry feeding to reduce the competitive efficacy of bacterial resistance and its residuals in poultry products. Using antibiotics and hormones in feed not only raises production costs but they also get incorporated into the processing of meat and eggs and increase microbial resistance. Several synthetic medicine and growth promoters are fortified into broilers diets for fast growth. However, their use still shows some drawbacks, such as high costs, adverse side effects on bird health, and extended residual properties. Thus, the primary aim of poultry production is to obtain higher performance through increasing the feed efficiency besides getting safety products for consumption. Due to their nutritional and immunological effects, such as improved feed efficiency, regulation of endogenous digestive enzymes, immune response stimulation, antiviral, antibacterial, and antioxidant properties, medicinal plants seem to be of great importance. Turmeric (*Curcuma longa*) is a useful medicinal herb belonging to the ginger family, Zingiberaceae which is inherent to the Asian subcontinent.

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It has numerous medicinal properties, such as antimicrobial, anti-inflammatory, antimutagenic activities, and other beneficial health applications. Furthermore, turmeric contains several biologically active compounds such as curcumin, bisdemethoxy curcumin, demethoxy-curcumin, and tetrahydrocurcuminoids, which may be responsible for these beneficial effects. Besides, turmeric is safe due to its low toxicity index and could be effective against aflatoxin-induced mutagenicity and hepatocarcinogenicity. In this chapter, we will discuss the valuable effects of turmeric in terms of the production, carcass traits, and ameliorative role in bird .

Keywords: Growth promoter, Immunomodulation, Poultry, Turmeric.

INTRODUCTION

Feed additives are often used in the production of poultry to enhance the quality of production, performance and bird health [1]. Using low prophylactic levels of antibiotics to improve growth, as well as gastrointestinal health, has become a common procedure in modern poultry production industries [2]. Furthermore, inappropriate and unnecessary use of antibiotics may lead to the development of antibiotic-resistant bacterial strains, which adversely affect both bird and consumers' health [3]. Thus, using safe, natural herbs as feed additives to substitute the antibiotics as growth promoters and efficiency enhancers has a tremendous and critical demand for the poultry industry [4]. Several medicinal plants show potential as growth promoters, antibacterials, immunostimulants, antioxidants, and anti-stress agents [5 - 8]. They could also be valuable for the prevention and cure of various types of diseases, disorders, and illnesses [9].

Turmeric (*Curcuma longa*) is a seasonal flowering plant of the family Zingiberaceae, and grows predominantly in tropical regions of India and Southern East Asia [10]. It is a three to five feet high stemless plant with yellowish leaves, yellow rhizome/root, and white clustered flowers [11]. Generally, turmeric is a medicinal plant used as an ingredient in the diet to enhance the appearance, flavor, palatability, and preservation of feed [12]. Also, it has antioxidant, antibacterial, antifungal, antiprotozoal, antiviral, anti-inflammation, anticarcinogenic, antihypertensive, and hypo-cholesteric activities [13]. Curcuminoid and a polyphenol present in the form of curcumin are the active principles of the turmeric mode of action [14]. Curcumin is an orange-yellow turmeric pigment derived by extracting 40% of the oleoresin turmeric oil content [15]. The turmeric oil contains mainly turmerone and curlone compounds, which have also been tested against several bacterial strains (*Staphylococcus aureus, Bacillus cereus, Bacillus coagulans, Bacillus subtilis, Escherichia coli,* and *Pseudomonas aeruginosa*) [16]. Besides, numerous medicinal properties of turmeric are well documented in several poultry studies [17 - 20]. The use of herbal products is gaining increasing attention in both the industry and scientific circles. Thus, the present chapter will discuss the beneficial applications and mode of actions of *Curcuma longa*, including its health impact and preventive action on diseases. Also, we will present the nutritional role of turmeric and its effect on production and carcass traits in broilers and hens. The chapter will be useful for veterinary professionals, people involved in pharmaceutical industries, researchers, scientists, and the poultry industry.

TURMERIC ACTIVE CONSTITUENTS

Turmeric is commonly used as the primary provenance of curcumin in several medications (Fig. **1**) [21].

The chemical analysis of turmeric powder shows that it consists of nearly 60–70% carbohydrates, 6–13% moisture, 6–8% crude protein, 5–10% crude fat, 3–7% minerals, 3–7% essential oils, 2–7% fiber, and 1–6% of curcumin-related compounds [22]. Several active ingredients in turmeric rhizomes are volatile and non-volatile components [23]. Within turmeric, there are 34 essential oils, including, for example, turmerone, germacrone, atlantone and zingiberene [24]. Coloring agents, which are the primary sources of several phenolic compounds such as demethoxycurcumin, curcumin, tetrahydrocurcumin, and bisdemethoxycurcumin, in addition to the colorless metabolites, are the main active substances in non-volatile compounds [25]. While curcuminoids are the principal active substances in volatile oil [26]. Turmeric powder contains approximately 3.14% curcumin, the content of which differs among *Curcuma longa* species [27]. Curcumin "diferuloylmethane" with the chemical formula of (1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-dione) and with 368,379 molecular weight and other curcuminoids are the major phytochemicals of *Curcuma longa* L. belonging to the family of Zingiberaceae, rhizome [28]. Curcumin can be metabolized with catabolic products, including vanillic acid and ferulic acid, into curcumin-sulfate, curcumin-glucuronide [29]. Thus, curcumin has a surprisingly wide range of pleiotropic beneficial properties and activities, including survival pathways regulated by NF-κBand Akt, the growth factors; Nrf2 mediated cytoprotective pathways, metastatic and angiogenic pathways and acts as a free radical scavenger and hydrogen donor with pro- and antioxidant activity due to demethoxycurcumin and bisdemethoxycurcumin, in addition to the anti-inflammatory, hypolipidemic, antioxidant, antiviral, antibacterial, antifungal, anticancer and chemotherapeutic activities [30 - 32].

CHAPTER 9

Nutritional and Promising Therapeutic Potential of Chia Seed as a Feed Additive in Poultry

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Abstract: Chia (*Salvia hispanica* L.) is an annual summer crop that belongs to the Labiate family. Chia seeds are a rich source of nutrients like polyunsaturated omega-3 fatty acids (PUFA), which safeguard against inflammation, improve performance and could be used for the enrichment of eggs and meat with omega-3 contents in poultry. These seeds are also rich in polyphenols, which can protect the body against cancer, aging and free radicals. Quercetin, chlorogenic acid, kaempferol, caffeic acid, and myricetin are reported as valuable sources of antioxidants in chia seed. It is believed that these seeds have antidepressant, anti-blood clotting, and hepato-protective features, along with anti-inflammatory and anti-carcinogenic effects. They have a positive role in diabetes, dyslipidemia, antianxiety, hypertension and constipation in humans. Furthermore, it is a potential source of dietary fiber, which helps to support the gastrointestinal function. Chia seeds also have a high concentration of beneficial unsaturated fatty acids, phenolic compounds, vitamins and minerals. Chia seeds contain a good balance of non-essential and essential amino acids. The addition of chia seed in poultry feed resulted in an increase of omega-3 fatty acids content in both eggs and meat. Moreover, it also offers advantages over other sources of PUFA for poultry feeding due to the absence of adverse effects on bird's health. Chia seeds do not have any toxic compounds or anti-nutritional factors and have been added to poultry feed up to 30%, which proved it as a safe feed ingredient for poultry diets. However, further studies are required to explore its potential application as a promising feed additive, growth promoter and antioxidant for commercial poultry diets.

Keywords: Antioxidant, Feed additive, Nutritional value, Poultry, *Salvia hispanica* seed.

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INTRODUCTION

In many countries particularly the European Union, due to the ban on the use of chemical growth promoters (antibiotics) as a growth factor, the researchers have tried to find and replace them with natural feed additives such as herbal plants, prebiotics, and probiotics in animal nutrition [1, 2]. These alternatives should be efficient against the pathogenic gastrointestinal microorganisms by improving immunity and feed efficiency. Thus, one of the best options for replacing synthetic antibiotics as growth enhancers is the incorporation of medicinal plants and their extracts [3, 4]. As a result, many experiments have been conducted to evaluate the effects of medicinal/herbal plant materials and their extracts as an alternative for antimicrobial growth promoter (AGP) sources and they have reported some significant effects on chicken growth performance [5 - 12]. *Salvia hispanica* L. is known as chia that is native to Southern Mexico and Northern Guatemala and is well-known as a medicinal herbaceous plant [13]. The genus *Salvia* consists of about 900 species and its name is derived from the Latin word “salvere”, referring to the therapeutic activities of *Salvia officinalis* that is also known as a medicinal herb [14]. Chia contains high levels of α-linolenic acid, which does not contain any of the vitamin B6 antagonists or anti-nutritional factors [15, 16]. The medical researches indicated that the consumption of α-linolenic acid might reduce the risks of cardiovascular-related disorders [17, 18]. The scientific evidence obtained from animal studies, epidemiological, and clinical studies in humans have shown that consuming lipids rich in x-3 fatty acids can diminish coronary heart disease. Chia seed is composed of 30-33% fats, 26-41% carbohydrates, 15-25% protein, 18–30% dietary fiber, 4-5% ash, minerals, vitamins, and almost 92% dry matter. High amounts of antioxidants are derived from this seed [19], and also it is reported to be free of mycotoxins and gluten [20, 21].

The seeds of chia are frequently used to improve the omega-3 fatty acids content in poultry products like meat and eggs as well [22]. The important content of chia seeds is a fiber that is studied for its insoluble and soluble fractions, viscosity and water holding capacity [23] and it can be used as a suspending agent, an emulsifier and a foam stabilizer in poultry feed and for pharmaceutical purposes [24]. The fresh matter of chia seed derived from a chia plant has almost 230 g oil/kg [25]. Chia seed is high in proteins and essential amino acids [26] and it also contains some compounds such as quercetin, caffeic acid, myricetin, and kaempferol [27, 28]. Chia seeds and meal do not cause any digestive disorders that are associated with other polyunsaturated fatty acid (PUFA) sources such as marine products or flaxseed, and also do not have fishy flavor [29, 30].

The commercialization of chia seed products as a feed for dogs, horses, cats, pigs, and avian species is quickly developing across the globe. The scientific studies have reported that the nutritional advantages of chia seed in the poultry diet are higher than the other PUFA sources [31, 32]. The chia seed and its valuable components showed that it has great potential to take part in health, animal feed, nutraceuticals, pharmaceuticals, *etc.* [33].

The therapeutic effects of chia seed on controlling diseases, clinical or sub-clinical symptoms, and immune-boosting effects have been studied in humans and different animal models. But, regarding its use in the poultry industry, limited research has been carried out to explore its potential role as an ingredient for poultry diets. So, the aim of this chapter is to gather favorable evidence for poultry researchers to focus on chia seeds as a potential feed ingredient and/or feed additive owing to its toxin and gluten-free properity, which makes it a safe feed ingredient in the poultry diet.

DESCRIPTION OF CHIA SEED

The dimension of chia seeds is characterized by almost 0.88 mm thickness, 1.21 mm width and 1.87mm length having an oval shape with tiny dark spots and colors ranging from beige to dark coffee [34]. Ixtaina *et al*. [19], reported that the white seeds are denser and heavier than the darker ones, as shown in Fig. (**1**). If seeds of this plant are kept clean and dry, they can be usable for a long time because of their antioxidant contents that prevent the degradation of essential oils.

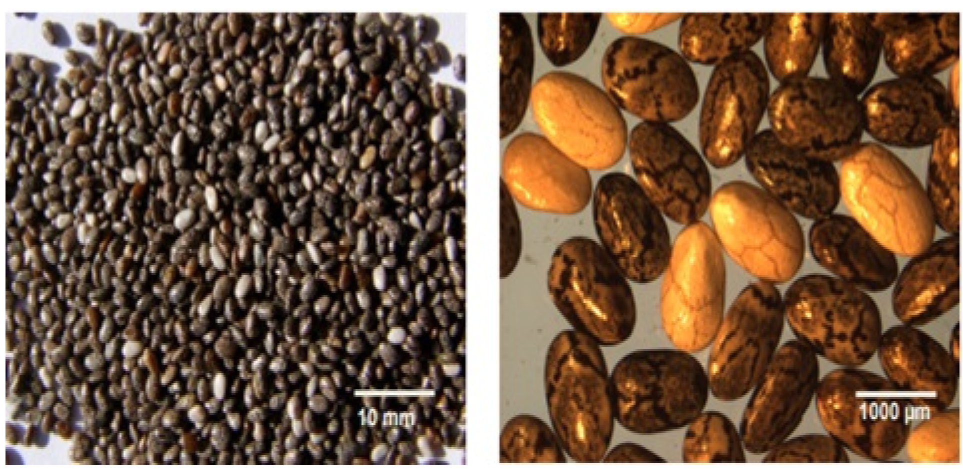

Fig. (1). The form and size of chia seeds.

PHYTOCHEMICALS IN CHIA SEED

As described by Ayerza and Coates [35], the polyphenolic compounds present in chia seeds include; flavonol glycosides, myricetin, chlorogenic acid, quercetin,

CHAPTER 10

Cassia Fistula: Potential Health-Promoting Candidate for Livestock and Poultry

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Abstract: The beneficial uses of natural herbal plants in medical sciences have achieved great attention due to promising health benefits in comparison with synthetic pharmaceutics. *Cassia fistula* (CF) is one of the most famous medicinal plants due to its broad range of incredible biological functions, such as laxative or purgative, antidiabetic, hypolipidemic, hepatoprotective, antioxidant, anti-inflammatory, antipyretic, antitussive, antimicrobial, anticancer, antiparasitic and wound healing as well. Moreover, flavonoids derived from CF, such as tannins and glycosides, exhibit a broad spectrum of therapeutic activities and low toxic effects. Previously most studies discussed *in vitro*-based models, humans, and rodents. The aim of this review is to highlight the medicinal importance of CF on the production performance of animals. Up to now, there are still many research areas waiting to be explored, such as finding out the metabolic pathway of flavonoids of CF in different animal models, mainly focus on poultry.

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Therefore, the present chapter aimed to attract attention to health-promoting and medicinal uses of this plant in poultry and animals. The above-mentioned research will provide further medicinal development of this genus.

Keywords: Animals, *Cassia fistula*, Growth promoter, Medicinal properties, Poultry.

INTRODUCTION

According to the World Health Organization (WHO) recommendations, around 70 percent of the world's population utilizes folk medicine to achieve their main health requirements. The developing nations are using ethnomedicine to cure medical problems [1, 2]. The drugs and formulations from the natural origin are commonly believed to be having less toxic and undesirable adverse effects when compared to synthetic origin [1]. In the current century, improving animal and poultry production performance by dietary manipulation is the main target of nutritionists. In the modification of NRC nutrient recommendations [3, 4], using feed additives like enzymes, organic acids and medicinal plants has been reported by many researchers [5 - 9]. *Cassia fistula* (CF) is popularly well known as a golden shower tree and belongs to the *Caesalpiniaceae* family; it is broadly employed for its medicinal qualities. It has purgative effects due to the presence of wax aloin and a tonic [10] and has been documented to treat numerous additional gastrointestinal disorders such as healing ulcers [11]. In traditional/folk medicine, CF is among the important medicinal plant principally used in Unani and Ayurvedic medicines; this plant has been implemented to be useful against skin diseases, liver troubles, tuberculosis glands and its use in the treatment of haematemesis, pruritus, leucoderma and diabetes [12]. Traditionally, the plant is also used as an infusion, decoction, or powder, either singly or along with a mixture of other medicinal plants. Recently, commercial preparations tend to be the standardized extracts of the whole plant. The medicinal plant, its extracts and phytochemicals (extracts from flower, seed, stem barks, fruit and leaf) have been reported for fascinating biological and pharmacological activities, such as antioxidant, anticancer, antidiabetic, anti-inflammatory, hepatoprotective, antiaging, antibacterial, antifungal, analgesic and antidiabetic properties [13 - 19]. In the folk medicine therapeutic system, various diseases and pathological conditions are commonly cured with CF believed to be self-limiting, therefore health-promoting effects require further investigations. Poultry diet is limiting and very expensive for the smallholder resource-poor farmers. Therefore, it is necessary to find cheaper alternative protein sources that sustain productivity and increase protein source options for smallholder poultry farmers. This chapter summarizes the current scientific findings and suggests areas where further research is needed in animal and poultry and also to be the need of time to verify the therapeutic efficacy of *Cassia fistula* in different animals and poultry industries.

PLANT BIOGRAPHY

Cassia fistula is native to the Indian subcontinent and adjacent areas of Southeast Asia. It grows throughout southern Pakistan and eastward throughout India, Bangladesh, China, Hong Kong, Myanmar, Philippines, Malaysia, Indonesia, and Thailand. It is an ornamental plant and is commonly used for traditional herbal medicine. This plant is widely grown in the subcontinent and known by different local names (Fig. **1**). The taxonomical classification of CF is shown in Fig. (**2**). *Cassia fistula* is a modest-sized deciduous tree with 10 m in height, flowers-yellow, leaves swap, pinnate, 30-40 cm long, with 4-8 pairs of ovate leaflets, 7.5-15 cm long and 2-5 cm large. Fruits are pendulous, cylindrical, brown, septate, 25-50 cm long, 1.5-3 cm in diameter, with 25-100 seeds. Seeds are lenticular, light brown, and lustrous.

APPLICATION IN HERBAL MEDICINE

The diverse Cassia species available globally are implemented in herbal medicine. The CF is, no doubt, a modest laxative and can be used safely while treating the children [20]. *Cassia fistula*'s emulsion can be as effective as polyethylene glycol in the treatment of children with functional constipation [21], while the use of leaves and bark with high doses can induce vomiting, nausea, abdominal pain and cramps. *Cassia fistula* is used as a therapy for tumors (abdomen, glands, liver, stomach and throat), burns, cancer, constipation, convulsions, diarrhea, delirium, dysuria, gravel, epilepsy, hematuria, pimples, and glandular tumors. In Ayurvedic medicine systems, the seeds are attributed with antibilious, aperitif, carminative, and laxative properties, while the root is used for burning sensations, adenopathy, leprosy, syphilis, skin diseases and tubercular glands. The leaves are employed there for erysipelas, rheumatism, malaria and ulcers. In Brazil, the seeds are employed as a laxative and the leaves and/or bark as an analgesic and for inflammation [22, 23]. Recently, natural products made from CF plant have been used in an assortment of cosmetic applications as a whitening agent and a source of nutrition.

APPLICATIONS IN AYURVEDIC MEDICINE

A large number of plant species have been used in the traditional Indian Ayurvedic medicine to improve the health status by treating hyperlipidemia like CF, known as Indian Laburnum, commonly found in Pakistan, India, Bangladesh, South America and Tropical Africa as well as the West Indies. In India, the rural people consume the mature pulp of fruit as a purgative and against abdominal

CHAPTER 11

Moringa (*Moringa oleifera*) and its Role in Poultry Nutrition

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Abstract: Utilizing novel rations in chicken feeding in developing countries has drawn considerable interest in the recent few years. *Moringa oleifera* is originally planted in India. It is cultivated in tropical and subtropical regions all over the world. It is famous as ‘drumstick tree’ or ‘horseradish tree’. *Moringa* can bear both aridity rime and intense moderate conditions. Thus, it is vastly planted in numerous soils. Each part of this tree is convenient for either nutritional or merchant targets. In general, it has elevated nutritious values. Leaves contain a high amount of minerals, essential phytochemicals and vitamins. Leaves can be utilized to cure undernourishment. In addition, it could be utilized as a prospective antioxidant, an anticancer, antidiabetic, anti-inflammatory and antimicrobial agent. Moringa contains a crude protein that varies from 71.2 to 391.7 g/kg, and varying parts of this plant are the reason for this variation. But *Moringa* holds anti-nutritional factors like phytates, trypsin inhibitors, oxalates, tannins, saponins and cyanide that negatively influence the metabolism of protein and mineral, as well its bioavailability to the chick. Phosphorus bioavailability can be boosted by adding phytase to the diet, which breaks down phytate that binds phosphorus. Previous studies demonstrated that the integration of *Moringa* in poultry diets could enhance productive performance traits and chickens' growth. Thus, this chapter compiles the usage and possible toxicity of *Moringa oleifera* and its characterization. In addition, the nutritional composition, phytochemicals, antioxidants of *Moringa oleifera* leaf meal and its application in poultry diets are also outlined.

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Keywords: Antioxidants, Leafs, *Moringa oleifera*, Phytochemicals, Poultry, Productive performance.

INTRODUCTION

In past years, various phytogenic fodder inclusions, *i.e*., aromatic plants or their essential oil, have been studied in chickens [1 - 3]. Even their various species with different inclusion levels have been investigated to detect a safe, natural and cheap feed additive with the high frugal product [4]. The feed inclusion level of aromatic plant parts varied from 0.01 to 30 g/kg diet, *e.g.*, rosemary powder at 0.4 to 0.5 g/kg feed [5], anise seeds at 0.25 to 1.5 g/kg diet [6], yarrow, rosemary and marjoram at 10 g/kg feed [4], oregano addition at 10 to 30 g/kg feed [7] and rosemary at 5 to10 g/kg feed [4, 8], were shown for respectable positive influences in terms of poultry output and health. Essential oil feed inclusion levels are relatively lower than other plant parts but show an analogous level of influences. Examples comprise Essential oils from herbs such as thyme, marjoram, rosemary and yarrow at 1000 mg/kg feed [4], rosemary and sage extracts at 500 mg/kg of feed [9], anise oil at 100 to 400 mg/kg feed [2], thymol and cinnamaldehyde at 100 mg/kg feed [10] while oregano essential oil at 50 to 300 mg/kg of feed [11 - 13].

The usage of phytogenic compounds in fodder could be the perfect feed quality. Firstly, their antioxidative and antibacterial properties (*e.g.*, rosmarinic acid, carvacrol, and thymol) engage together to enhance the overall fineness of mash [14]. Secondly, they have the capability to delay the development of mycotoxigenic fungi [15]. Phytogenic extracts/essential oils have antimycotic characteristics, which could be beneficial in prohibiting mycotoxin production in stored wheat grains. The development of toxigenic fungi, *e.g.*, *Fusarium moniliforme*, *Aspergillus ochraceus*, *Aspergillus parasiticus* and *Aspergillus flavus* could be mitigated by cinnamon, thyme and anise [16, 17]. The current chapter proposed to allow more information about uses, nutritional values and nature of *Moringa oleifera* as a hopeful material for poultry.

DESCRIPTION OF *MORINGA OLEIFERA*

Moringa oleifera was generally known as the “drumstick tree.” Other popular names include ben oil tree, horseradish tree or benzoyl tree. The tree is ‘multi-purpose’ as all of its parts (the pods, leaves, flowers, seeds, roots, and fruits) are eaten [18] (Fig. **1**).

Moringa oleifera is a deciduous, fast-growing tree. Its top most elevation could be 10-12, and its trunk could accomplish a diameter of 45 cm. The flowers are around 2.0 cm wide and 1.0-1.5 cm in length. Flowering begins through the first six months after cultivation. The fruit is a three-sided brown capsule of 20-45 cm size, pendulous, consists of spherical, dark brown seeds of about 1 cm diameter. The seeds possess three thin whitish wings, which are in charge of the smooth distribution of seed by the wind and water [19]. The tree needs an annual rainfall of 250 mm and 3000 mm and qualified for remaining alive at a temperature of 25-40°C, which makes it favorable for equatorial climates.

Kingdom:	**Plantae**
Subkingdom:	**Viridiplantae**
Infrakingdom:	**Streptophyta**
Superdivision:	**Embryophyta**
Division:	**Tracheophyta**
Subdivision:	**Spermatophytina**
Class:	**Magnoliopsida**
Superorder:	**Rosanae**
Order:	**Brassicales**
Family:	**Moringaceae**
Scientific name:	***Moringa oleifera* Lam.**

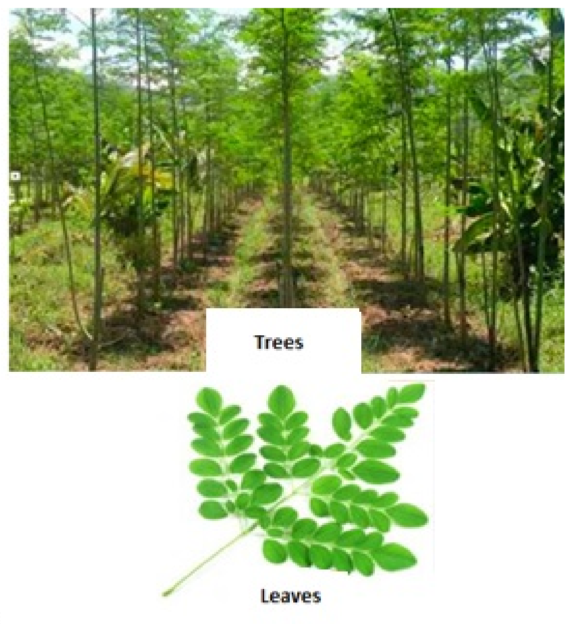

Fig. (1). Taxonomy of *Moringa Oliefera.*

USES OF *MORINGA OLEIFERA*

The most favorable character of *Moringa oleifera* is that all parts are treated as food. Through the drought period, its leaves could be utilized as a feed or food [20]. In Africa and Asia, *Moringa oleifera* flowers, pods, leaves, and roots are cooked as an alternate of vegetables [21]. Due to the perfect mineral profile, high protein and existence of vitamins, especially A, B, and C in leaves, make them quixotic for vegetarians, especially children, nursing mothers and pregnant [20]. *Moringa oleifera* seeds are eaten and roasted or cooked. They consist of 30 to 40 percent of edible oil (ben oil) [21]. Ben oil provides perfect amounts of tocopherols, sterols, and oleic acid, which stop rancidity [20]. It has medicinal characteristics depicted in Fig. (**2**) (antioxidant, antiviral, cardioprotective, anti-inflammatory, anticancer, and antiasthmatic). Terygospermin found in seeds of

CHAPTER 12

Green Tea (*Camellia sinensis*) and its Beneficial Role in Poultry Nutrition

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Abstract: Green tea (*Camellia sinensis*) is a famous herbal plant used as a potent antioxidant since ancient times with abundant health benefits. Numerous studies have shown the health benefits of green tea for many diseases. The objective of this article is to know the importance and various uses of green tea and its important constituents in poultry for safeguarding various health issues. The present review article also focuses on several beneficial health applications and salient medicinal properties of green tea that have not been comprehensively reviewed previously. Owing to the bioactive constituents, including caffeine, amino acids (AA), L-theanine, polyphenols/ flavonoids and carbohydrates, among other potent molecules, green tea has many pharmacological and physiological characteristics. Moreover, *Camellia sinensis* possesses essential biological compounds such as alkaloids, carotenoids, minerals, amino acids, carbohydrates, lipids, and volatile compounds. Based on scientific literature evidence, green tea has multifunctional applications in livestock animal sectors of dairy, goat and poultry industry. Green tea active ingredients have been shown to possess many health benefits with various mechanisms like antioxidative, anti-inflammatory, antiarthritic, antistress, hypolipidemic, hypocholesterolemic, skin/collagen protective, hepatoprotective, antidiabetic, antimicrobial, anti-infective, anti-parasitic, anti-cancerous, inhibition of tumorigenesis and angiogenesis, and improving memory and bone health. The findings presented would be useful for poultry researchers and farmers and would help to propagate the multidimensional health benefits of green tea.

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Keywords: Animal, Applications, Green tea, Health, L-theanine, Poultry.

INTRODUCTION

Tea was first used in China as a medicinal drink and later became a popular beverage next to water throughout the world [1]. A Chinese king Shen Nung, in 2737 BC for the first time, proposed the concept of using tea when accidentally, some tea leaves were boiled in water, and a lovely smell was produced [2]. Tea is cultivated in more than 45 countries throughout the world [3]. There are various kinds of tea available in the world tea market, like black (fully fermented), green(non-fermented), flavored, oolong (semi-fermented), white tea, *etc*., based on the manufacturing process [4]. In Europe, South Asia, and North America, the most popular is black tea, whereas oolong and green teas are consumed mainly in East Asian countries [5]. Green tea is basically made from the leaves of a plant scientifically known as *Camellia sinensis*, which has been used in different parts of the world. Green tea is thought to contain higher polyphenols and and flavonoids due to being non-fermented and therefore has greater antioxidant potential and health benefits than black tea [5, 6]. The major polyphenolic compounds found in green tea are catechins, epicatechin, epicatechin-3-gallate, and epigallocatechin-3-gallate [7]. Besides human consumption, low-grade green tea and green tea byproducts or spent tea has been used as an ingredient for animal feeds. Supplementation of green tea has been studied by several authors in fish [8], quails [9], ruminants [10], broilers [11, 12] and layer chickens [13, 14]. Green tea, the derivatives, and byproducts of green tea such as green tea extracts, green tea leaves, spent tea, green tea flowers and green tea polyphenols have been used as feed ingredients for improving the performance of poultry [13 - 15]. Recently, green tea powder supplementation in poultry diet showed a positive response for production parameters, immunity, growth and carcass characteristics [16, 17]. There are other plant secondary metabolites such as alkaloids and saponins found in green tea leaves. However, in comparison to black tea, the most important metabolites after catechin are theanine. In 1949, L-theanine was discovered in the leaves of green tea. This caramel-flavored attractive aromatic amino acid is a unique taste constituent of tea and helps to alleviate tea polyphenols astringency and caffeine bitterness [18]. L-theanine as a safe and non-toxic photogenic food supplement was suggested through different technical, safety and toxicological evaluations. L-theanine was synthesized chemically for the first time from aqueous ethylamine and pyrrolidone carboxylic acid [19].

The non-protein L-theanine (γ-Glutamylethylamide) is found mostly in the leaves of tea plants [20]. Dietary supplementation of L-theanine mitigated the damage induced by reactive oxygen species (ROS) [21]. Catechins of green tea can bind with many minerals and hence affect their metabolism [22]. Excess uptake reduces zinc and iron level; enhances manganese; however, the final blood plasma concentration of copper is not altered greatly [23, 24]. Wen [25] demonstrated that adding 400 mg L-theanine/kg daily in the diet increases the level of secretory IgA in the jejunum and the levels of IL-2 and IFN- γ in the serum of chickens. Theanine can reduce the toxic side impacts stimulated by anticancer drugs and can relieve lipid peroxidation and oxidative stress [26].

HEALTH BENEFITS ON POULTRY SPECIES

Green tea has a beneficial effect on poultry due to its polyphenolic contents having strong antioxidant properties [27]. *Camellia sinensis* contains natural flavonoids that have anti-coccidial properties [28]. The recent investigations assured that supplementing of green tea by-products to broilers and layers diets can enhance performance and decline the amount of cholesterol in egg yolk and blood serum, besides its impact on the criteria of egg quality. Supplementation of by-products derived from green tea minimizes the numbers of all microflora in caecum as a result of its antimicrobial impact [14].

Broilers Chickens

A limited number of studies in broiler chicken nutrition describing the supplementation of green tea leaves, extracts or powder have been published. However, the results are very inconsistent amongst studies. Supplementing green tea extracts at a rate of 200 mg kg^{-1} diet showed a positive response on the growth performance of broiler chicken [29]. Khalaji *et al*. [30] did not find any significant effect of green tea on broiler growth at a rate of 300 mg kg^{-1}. Growth parameters and feed intake level also were declined in treated broiler chicken fed with green tea extracts at 500 mg kg^{-1} [30]. Uuganbayar [31] claimed that 1% to 1.50% green tea supplementation in broiler diet reduced chicks body weight gain [32].

Farahat *et al*. [11] and Cao *et al*. [12] did not find any significant differences in body weight, daily gain, daily feed intake and feed conversion ratio of broiler chickens after supplementation of different concentrations of green tea extract (125 to 2000mg kg^{-1}). They also added that birds fed diets supplemented with graded concentrations of green extract tea had improved antioxidant and immunostimulant traits. Furthermore, the antibody titer against Newcastle disease virus vaccines was increased in chicks fed diets supplemented with green tea [11].

Yang *et al*. [33] showed insignificant improvement in feed efficiency percent and growth performance of broiler chickens by green tea by-product. The authors added that supplementing diets with powdered green tea by-product decreased blood LDL cholesterol comparing to the control group while increased HDL levels docosahexaenoic acid (DHA) in the blood. Moreover, cholesterol content in

CHAPTER 13

Beneficial Impacts of Essential Oils on Poultry Health and Production

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Abstract: With the rapid growth of the poultry sector, a major human health concern is noticed relating to the excessive and uncontrolled abuse of antibiotics, which leads to the development of antibiotic-resistant bacteria. Antibiotics are used in sub-therapeutic doses as antimicrobial agents for rapid growth performance in poultry and for prevention of diseases. For this reason, there is a need to develop alternatives to antibiotics. The beneficial effects of plants and plant extracts that have traditional use are evaluated in many studies. The most common beneficial effects of these plants and their extracts are stimulating endogenous digestive enzymes and antioxidants. Essential oils (EOs) have a wide variety of effects, including antimicrobial, antioxidants, and digestive stimulant activities. Essential oils have been demonstrated to positively affect growth performance, gut health, and meat quality, but the responses are inconsistent. The inconsistencies have been related to the species/subspecies of the plant, harvest time, geographical location, and plant part used that can affect the EOs structure. The oils undergo a patented micro fusion process that creates a surface area of oil droplets that is 20 times greater than other commercially available oilsthus increasing the stability and effectiveness of the oils. The EOs exhibit high antioxidant activity, which is attributed to its two main phenols, carvacrol, and thymol. Conclusively, essential oils can be used in poultry nutrition, but still need more studies, especially metabolism, and the optimum dose in various poultry species.

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Keywords: Antibiotics, Carvacrol, Essential oils, Growth, Poultry, Resveratrol, Thymol.

INTRODUCTION

Generally, feed additives enhanced the poultry growth capacity, but some may be added to replace antibiotics for the prevention of diseases. However, there is a large difference in the efficacy of feed additives. Of the alternatives listed, phytochemicals, specifically essential oils (EOs), have been shown to have the most inconsistent results [1 - 3]. Essential oils are aromatic oils that can be extracted from plant material, typically by distillation. There are about 300 EOs that are commercially available, and the inconsistency in results may be due to this wide variety of oils, or the fact that the chemical compounds in oils can be affected by species, climatic conditions, harvest time, and plant part [4, 5]. The EOs have been shown to impact growth efficiency and gut health of poultry. Mathlouthi *et al*. [6] reported that broilers fed avilamycin (0.04/kg), rosemary, and oregano (0.1 g/kg), or a blend of EOs (1g/kg) had significantly increased weight compared to control groups. Alp *et al*. [7] concluded that broilers fed an anticoccidial (100 mg/kg) or oregano essential oil (0.3 g/kg) had improved feed conversion ratio (FCR) over broilers on a control diet, but there were no differences in the final weight on day 42. While, other research indicates that EOs showed a negative or minimal effect on growth performance [8].

Although the exact mechanism of EOs in enhancing growth performance is not known, Jang *et al*. [9] reported that broilers that were fed a blend of EOs had increased pancreatic amylase, trypsin, and maltase activity in the small intestine as compared to control birds. The increased digestive secretions, which could result in increased nutrient absorption may assist in the antimicrobial activity of EOs. EOs can affect gut health in two major ways: shifts in gut microbiota and changes in the microscopic anatomy of the small intestine [1, 10, 11]. The combination of these two effects leads to an increased ability of the poultry to combat disease caused by pathogenic organisms.

However, research on the impact of EOs on the histology of the intestine in poultry is limited, especially research on broilers that are under a coccidiosis disease challenge. Basmacioğlu *et al.* [10] investigated the impact of EOs blend on the ileum histology and found that broilers that were fed on the EOs mixture had increased villus height and lower crypt depth at 42 days of age over compared to control birds.. OviedoRondón *et al.* [12] found that feeding EOs to coccidiosis-infected broilers impacted the microbial community in infected broilers by preventing drastic shifts in the microbial populations after the infection. Shifts in microbial populations can stimulate an immune response because new antigens were developed [4]. Furthermore, Evans *et al.* [13] observed a decrease in the oocyst excretion from chickens after feeding on a blend of EOs. Essential oils are also known to decrease the lipid oxidation of meat due to their antioxidant activity [11]. Essential oils, particularly oregano, sage, and rosemary, are known to have a high antioxidant activity [1]. Oregano is derived from *Origanum vulgare* and both carvacrol and thymol give it its antioxidant effect [8]. The present chapter summarizes the beneficial impacts of different EOs on poultry health and production.

SOME TYPES OF ESSENTIAL OILS

Thymol

Sources of Thymol

Thymol is a component of several medicinal plants, such as *Thymus zygis*, *Thymus vulgaris*, *Origanum compactum*, *Origanum onites*, *Origanum dictamnus*, *Monarda fistulosa*, *Thymus hyemalis*, a *Thymus glandulosus*, and *Origanum vulgare,* as recorded by Lee *et al.* [14] also, the North American wildflowers and bee balms *Monarda didyma* are considered as natural sources of thymol [15].

CHEMICAL AND PHYSICAL CHARACTERISTICS

Thymol is a white crystalline substance and is similar in taste to carvacrol. The melting range of thymol is 49 to 51°C, while the boiling point is 232°C. Due to the deprotonating of the phenol, it is soluble in alcohol and alkaline solutions but less soluble in water at neutral pH [16]. It absorbs the UV radiation until 274 nm. The structural formula of thymol is shown in Fig. (**1**).

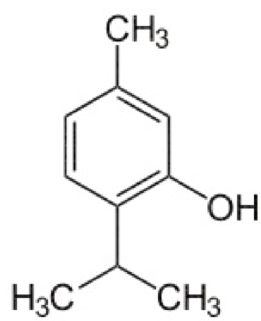

Fig. (1). Basic structural formula of Thymol.

CHAPTER 14

Organic Acids as Eco-Friendly Growth Promoters in Poultry Feed

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Abstract: Organic acids (OAs) have been used as natural preservatives for food products and as hygiene promoters to inhibit microbial growth, thereby improving the freshness and shelf-life of food items. The impact of OAs on microbial growth makes it an alternative to antibiotic growth promoters. The characteristic of inhibiting microbial growth is a useful feature that has been recently used in poultry production. Organic acids are chemically weak, and they modulate the beneficial competitive exclusion in the gastrointestinal tract (GIT) and diminish the production of metabolites harmful to the body by decreasing the proliferation and colonization of pathogenic bacteria in the GIT. Further, they improve the ability of the intestinal wall to absorb nutrients by improving the structure of the villi and the digestive secretions that lead to enhanced absorption of proteins, carbohydrates, and minerals.

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The use of 15g/kg of citric acid in broiler diets reduced the cecal total bacterial count and *Enterobacteriaceae* by 62.26% and 80%, respectively, in comparison with control. However, the same level of fumaric acid reduced the cecal total bacterial count and *Enterobacteriaceae* by 88.63 and 78.57%, respectively. Similarly, the inclusion of 30g/kg of fumaric acid reduced the cecal total bacterial count and *Enterobacteriaceae* by 95.84 and 88.57%, respectively. The immunity of broilers can thus be improved as a normal consequence of all previously mentioned advantages. The use of 0.30 g/kg blends of sorbic acid, fumaric acid, and thymol improved the spleen size of broiler chickens by 50% when compared to control. Dietary inclusion of formic acid up to 5 and 10 g/kg significantly improved feed conversion ratio by 9.37 and 16.66% and improved ileal digestibility of crude protein by 19.85 and 21.08%, respectively. This chapter summarizes the possible modes of action of dietary OAs and their effects on the growth and health of poultry.

Keywords: Antimicrobial activity, Nutrition, Organic acid types, Performance, Poultry.

INTRODUCTION

Antibiotic growth promoters (AGPs) are either banned or under control as they lead to antibiotic resistance in both humans and animals [1 - 4]. In January 2006, the European Union, as a step in minimizing and eliminating the use of AGPs in the poultry industry, started with the prevention of the use of sub-therapeutic antibiotics (European Parliament and Council Regulation (EC) No 1831/2003) in food production. However, the removal of AGPs resulted in delayed performance effects, therefore, researchers developed several alternatives to AGPs such as prebiotics, probiotics, organic minerals, bacteriophages, plant additives, and organic acids (OAs) [5 - 11].

Dietary acids used in poultry nutrition are divided into organic and inorganic acids [12, 13]. OAs are defined as carboxylic acids that have R-COOH group in their chemical structure such as fatty acids and among them only OAs with excellent physical and chemical characteristics are used in the poultry industry. The commonly used acids are the short-chain OAs such as formic, acetic, propionic, and butyric acids, in addition to other OAs such as lactic, malic, tartaric, fumaric, and citric acids [14]. Dietary OA supplementation gained considerable attention as an alternative to AGPs owing to its effect on pathogenic bacteria; it reduces the pH in the gastrointestinal tract (GIT), thus improving the absorption of different nutrients in poultry [15, 16]. Further, OAs improve growth performance, feed utilisation, and disease resistance [14, 17, 18]. The main objective of this chapter is to describe the workable mode of action of dietary OAs for poultry and its effects on the growth rate and health aspects.

DEFINITION AND CHEMICAL STRUCTURE OF ORGANIC ACIDS [OAS]

R-COOH group is the main component of the OA structure that gives it acidic properties; such as fatty and amino acids. In general, OAs are weak acids that cannot completely dissociate in water. The most important property for measuring the strength and activity of an OA is the measure of its dissociation, which is determined using pKa; the pKa value which is lower in a healthier and more dissociable acid. To have an antimicrobial effect, the pKa value of the OA should be between 3–5 [14]; although all OAs exhibit partial dissociation, all of them do not have the same antimicrobial effect. Short-chain acids between C1 and C7 with one carboxylic group are formic, propionic, butyric acids tartaric, lactic, malic, and citric acids, which have antimicrobial properties. Furthermore, fumaric and sorbic acids have an extra advantage of an anti-fungal effect. OAs and their salts have not only an antimicrobial effect on both the feed and the GIT but also a performance enhancement effect [19].

Action Mechanisms of Dietary OAs

As OAs are not clearly described in previous articles, their application in broiler diets is limited. Several modes of actions have been proposed, and they focus on [a] the decrease in the pH in the feed and the GIT; [b] the increase in nutrient retention, which increases nutrient utilization; and [c] antimicrobial effects [9, 20, 21]. The dietary butyric acid and its salt could act asglycolysis intermediates accumulate in the cell, which confirms that butyrate is a preferred energy substrate over glucose. Further, dietary butyrate spares the oxidation of some amino acids, increasing their digestion and absorption. Al-Kassi and Mohssen [19] indicated that enzyme activity plays a role in the enhanced performance resulting from different doses of some OAs. This improved performance is partially attributed to the increase in pepsin activity, pancreatic enzyme activities [trypsin and lipase], and intestinal enzyme activities [leucine-aminopeptidase and phosphatases].

Antimicrobial Activity of OAs

Organic acids are economically viable and biologically active alternatives to AGPs. For several years, OAs have been added effectively in the feed of birds to reduce the presence of pathogens, especially *Salmonella* spp. and mycotoxins produced by fungi [22]. Attia *et al.* [23] reported that OAs modulate the intestinal pH, inhibit the growth of pathogenic microorganisms, and maintain the microbial balance in the GIT. Further, Saki *et al.* [24] and Nair and Johny [25] showed that

CHAPTER 15

Beneficial Impacts of Probiotics on Poultry Nutrition

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Abstract: Antibiotics have been commonly used as growth enhancers to promote performance and feed efficiency in poultry production. It is essential to find new and safe alternative compounds to antibiotics due to their numerous harmful effects, such as antibiotic resistance, destruction of the gastrointestinal microbiota community, and dysbacteriosis. Improving poultry production using probiotics as feed additives is one of the decent alternative options to antibiotics. Probiotics are described as "living microorganisms that confer a benefit on the host health when applied in adequate quantities". Probiotics as feed additives help in feed digestion by creating the nutrients in an available form to grow faster. Also, poultry diets supplemented with probiotics improve immunity status. Besides, fortified poultry diets with probiotics enhance meat characterization and egg quality traits. Additionally, the use of probiotics in poultry feed could prevent various infectious diseases. Thus, obtaining optimum results requires a good selection of probiotic strains. This chapter focuses on the probiotics' mode of action and their relevance in poultry diet supplementation to improve production and preserve poultry health.

Keywords: Health, Mechanisms, Performance, Poultry, Probiotics.

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INTRODUCTION

Since the 1940s, antibiotics have been used as feed additives or growth promoters. It was found that using chlortetracycline supplemented diets with *Streptomyces aureofaciens* enhanced the bird's growth performance [1]. Since 2006, the European Union (EU) has restricted antibiotics use as growth promoter agents or for food supplementation; the ban to the antibiotics use was due to induction of bacterial resistance strains against antibiotics used for a long time to prevent poultry diseases. Also, antibiotics induce several other problems, such as the destruction of various gastrointestinal beneficial microbiota. Furthermore, the EU observed that using antibiotics may lead to growth reduction, which might lead to a growing prevalence of subclinical dysbacteriosis and necrotic enteritis [2].

The demand from customers and their fears about the adverse effects of antibiotic usage in poultry diets and the EU's restriction encouraged researchers to consider antibiotics [3]. These alternatives are aimed to induce a high survival rate against infectious diseases, being a safe animal product while protecting the consumer's health and environment. Many research papers have accomplished to search for natural substances with similar positive effects as traditional growth promoters [4]. However, there are a variety of non-therapeutic compounds that could be alternative antibiotics. Amongst these, the common are prebiotics, probiotics, natural organic acids, synthetic enzymes, immunostimulant agents, bacterial proteinaceous, phages, phenolic compounds, nanoparticles, and volatile oils [5]. Probiotics' beneficial and protective effects are evident in numerous features. These could be recommended as a valuable strategy for preventing pathogenic bacteria and enhancing performance, egg quality, nutrients absorption, thereby improving poultry health [6 - 8]. Hence, probiotics play a vital role as the profit alternative to antibiotics due to their several useful impacts on animals' growth, involving fish and poultry [9].

FAO/WHO [10] defined probiotics as a live microorganism. When fortified into suitable quantities, itconfers a profit on the host health. Additionally, Hill, Guarner [11] recommended this definition of a probiotic. Likewise, Abd El-Hack, Mahgoub [12] have defined probiotics as live microorganisms used as feed supplements which positively enhanc the gastrointestinal tract *via* improving the gut microbiota community and improving nutrient absorption, performance, feed efficiency and economic aspects of poultry. This enhancement is supported by decreasing intestinal pH, microbiota and increasing the digestive enzymes [13, 14]. The probiotics' mode of action depends on the endogenous enzymes' stimulation, reduction of toxic substances, metabolism [15], and produced antibacterial compounds or vitamins [16]. Probiotic bacteria produce antibacterial proteins such as bacteriocins, which prevent toxins and promote the development of pathogenic bacterial strains [17]. Therefore, Probiotics enhance the immune status and improve resistance to pathogenic bacterial colonization [16]. For example, supplementation of chicken feed with *Enterococcus faecium*in showed an antimicrobial effect on the small intestine microflora [18]. Similar results were described by Latha, Vinothini [19] using *Streptomyces* sp. The study by Zhang, Cho [20] revealed that supplementing broiler diets with 10^5 cfu of *Bacillus subtilis* prevents necrotic enteritis, increases body weight and the thymus relative weight percentage. Furthermore, treating chicken with probiotic reduced the NH_3 and H_2S production levels in excretions, consequently leading to smaller odor emissions. Selecting suitable probiotic strains could reduce the harmful effects of antibiotic usage and have many useful outcomes due to its capability to prevent the pathogen's development.

Probiotics include numerous species, for example, beneficial intestinal microbiota, yeast or fungi, and the mainly recommended probiotics strains are *Bacillus subtilis, Bifidobacterium, Lactobacillus,* and *Streptococcus*, which inhibit the development of several pathogenic bacteria such as *Clostridium perfringens*, *Staphylococcus aureus, Salmonella typhimurium*, *Escherichia coli*, *etc.* [13 - 15, 21]. Besides, probiotics show several affirmative effects on the characterization of poultry meat [8, 16]. They enhance pH values, meat color, the profile of fatty acid, body chemical composition, the capacity of water retention and oxidative status [8, 12]. The probiotics also increase the meat contents from protein and fat and, therefore, the quality of meat. Abdurrahman, Pramono [22] stated a strong correlation between the oxidation of lipids and the feed quality deterioration. Other research may support this hypothesis by showing that the presence of *Aspergillus awamori* and *Saccharomyces cerevisiae* in chicken diets deprives the blood content of saturated fatty acids and increases polyunsaturated fatty acids [23]. Another related study carried out by Liu, Yan [24] found that supplementing broiler chicken diets with *Bacillus licheniformis* enhanced color, flavor and juiciness of produced meat, and increased the protein percentage and the respective aromatic and indispensable amino acids. Probiotics might prevent the incidence of the coccoidal diseases. Also, Giannenas, Papadopoulos [25] showed that treating chicken with probiotics in the absence of anticoccidial infections decreases the influence of parasite infection. Besides, using probiotics exerted coccidio static influence against *Eimeria tenella*. This could reduce the high risk and spread of coccidiosis and preserve gastrointestinal health [3].

This chapter highlights the probiotics sources, mode of action and healthy profits. Besides, the probiotics application in poultry diets, effects on the production and immune status have been defined here, which could be beneficial for researchers, veterinarians, nutritionists, and poultry producers.

CHAPTER 16

Nutritional Applications of Nanotechnology in Poultry with Special References to Minerals

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Abstract: The prefix "Nano" comes from the Latin word "nanus", which means "dwarf". Nanotechnology can be defined as the manipulation of materials at the nanoscale as it deals with particles sized between 1-100 nm. Nanotechnology, can open up opportunities for improving feed particles' utilization to the benefit of livestock production. Nanotechnology can also act as new vehicle for nutrient delivery to improve the digestion and absorption pathway for better nutrient metabolism. Minerals administered in the nanoparticle form as feed additives can pass through the wall of intestinal cells and other body cells more speedily than ordinary minerals, thus boosting their bioavailability. Therefore, nanotechnology can be used in animal feed to improve production performance, nutrient bioavailability, and livestock's immune response after considering nanotechnology's social, economic, legal and ethical implications. In conclusion, nanotechnology applications can provide solutions for poultry and livestock production systems to enhance the final product quality.

Keywords: Immunity, Nanotechnology, Nutrient bioavailability, Poultry, Production performance.

INTRODUCTION

The nanoparticles produced by various methods have been indicated as a novel industrial revolution as they have been utilized in numerous biological and industrial applications [1].

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The material at the nanometer dimension exhibits some novel properties (higher surface activity, greater specific surface area, stronger adsorbing ability, high catalytic efficiency) that are different from its normal-sized particles [2, 3]. In the last decades, in agricultural industry, the execution of nanotech-based tools has gained momentum. The implementation of nano-fertilizers and nano-pesticides as the nanotechnology intervention in the agriculture has enhanced the efficacy of nutrients and production level, and relieved the soil and water from pollutants. Concerning the animal production sector, the application of nanotechnology in this field facilitates the improvement of animal productivity, reduces the efforts and time, decreases the amounts of feed additives in diet, and lowers the cost of high prices of feed additives, thus leading to the sustainability of the livestock sector. Nanotechnology is important because it increases the trace mineral absorption by decreasing the antagonistic influence among the bi-valent cations. This novel approach can be exploited in poultry and livestock nutrition for better utilization of feedstuffs through an efficient uptake of nutrients and other supplements [4]. The use of nanoscale metal instead of inorganic mineral allows animals to absorb feed minerals, hence noticeably lessening environmental contamination risks [5, 6]. Although this technology is very promising for better poultry production, studies are very limited. There is still concern regarding the impact of nanoparticles on health and the environment. Thus, it is important to overview the applications of this technologyas a significant tool in promoting the poultry sector. This chapter covers different aspects of nanotechnology, including the role of nano Se, Zn and Cu particles in poultry nutrition and their up-coming prospectives.

EFFECTS OF NANO-SELENIUM ON POULTRY PERFORMANCE

Nano Se revealed strong nutritional and biological effects on improving poultry's productive and physiological performance (Fig. **1**). Table **1** shows different effects of nano-Se on various parameters of some poultry types during the last five years.

Table 1. Effects of nano-Se on poultry (available literature during the last five years).

Dose	Size of Nanoparticles	Poultry Type and Age	Effects	Reference
Nano Se (0.075, 0.15, 0.225 and 0.3 μg/egg)	< 100 nm	Broiler chicken *in ovo* (18^{th} day incubation)	No harmful effects on the developing embryo and hatchability	[7]
0.3 mg nano-Se/kg diet	100 to 500 nm	15-30 days old	Enhanced growth performance by improving antioxidative or immune properties	[8]

(Table 1) cont.....

Dose	Size of Nanoparticles	Poultry Type and Age	Effects	Reference
nano-Se (0.3mg/kg diet)	50-100 nm	Laying hen 9-20 weeks	Increased CBH response after immunization, antibody titers against SRBC, SOD and GSHPx activity	[9]
Se nanoparticles (0.075, 0.1125. 0.1875 and 0.225 mg/kg)	30 – 60 nm	Broiler chicken 1-35 days old	Improved oxidation resistance Increased serum SOD activity and GSHPx activity Decreased malondialdehyde level	[10]
Nano-Se(0.075, 0.1125, 0.1875 and 0.225 mg/kg)	30 – 60 nm	Broiler chicken 1-35 days old	Increased expression of liver GSHP×1 mRNA gene Improved oxidation resistance	[11]
0.5 mg/kg Nano-Se	20–80 nm	Broiler chicken 1-42 days old	Improvement of function, immunity and total antioxidant activity of blood serum	[12]
0.15 and 0.30 ppm Nano Se	80 nm	Broiler chicken 1-40 days old	Better growth performance and quality of broiler meat	[13]
nano-Se (0.1, 0.2, 0.3, 0.4, 0.5 mg/kg)	N/A	Broiler Chicken 1-42 days old	Improved growth performance, carcass parts and immune function Increased anti-ND hemagglutination inhibition titer No effect on glucose and total protein concentrations	[14]
50, 150 and 300 ppb nano Se	N/A	Giriraja chicken1-56 days old	Improved water holding capacity of meat No effect on production parameters and carcass characteristics	[15]

N/A = not available; CBH = cutaneous basophil hypersensitivity SRBC = sheep red blood cell; GSHPx = gluthatione peroxidase; SOD = superoxidase dismutase; ND = Newcastle disease.

Results showed that supplementing the diet with nano-Se improved the feed efficiency, body weight gain (BWG) and final body weight of Guangxi Yellow chicken [16]. This improvement may be attributed to small particle size and high specific surface area of nano-Se. Thus, good intestinal absorption could be obtained because of the creation of nanoemulsion droplets [17]. Enriching heat-stressed hens diets with nano-Se (0.3 ppm) provided the greatest value in both egg mass and egg production percentage (8.56%, 19.60%, respectively), also improving feed conversion ratio (FCR) by 4.05% compared to the organic selenium group [8]. Additionally, Ahmadi *et al.* [14] recently demonstrated that nano-Se dietary supplementation significantly enhanced feed efficiency and daily body gain in growing broilers. Also, they concluded that the addition of nano-Se

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