ANTIBIOTIC ALTERNATIVES IN POULTRY AND FISH FEED

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FOREWORD

I was glad when I got a request from Dr. Mohamed E. Abd El-Hack and Dr. Mahmoud Alagawany to write a brief foreword to their reprint book. For several years, I have admired their incredible work. Furthermore, poultry and fish products' consumers always search for organic products. So, the topic of this book is timely and globally needed for all people who produce or consume poultry and fish products.

Looking through this valuable book, I'm pleased with the authors' talent in writing such a useful book. It is a source of inspiration and information for those who work in poultry and fish production.

In conclusion, Dr. Abd El-Hack and Dr. Alagawany's book is peerless and a work to treasure for anyone interested in poultry and fish production. So, it is expected that readers will enjoy reading it and learn from it. Thank you, Dr. Abd El-Hack and Dr. Alagawany, for producing such a masterwork.

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PREFACE

For a long time ago, poultry keepers used to add trace levels of antibiotics to poultry feed to act as growth-promoting agents. This practice caused harmful impacts on poultry products' consumers because of antibiotic resistance. This led the European Union to ban the use of antibiotics in poultry feed. So, this book focuses on the use of antibiotic alternatives in poultry and fish feed. Also, it deals with the different impacts of these natural feed additives in poultry and fish nutrition on growth, production, reproduction and health status. This book contains 13 chapters contributed by 38 experts and scientists of animal, poultry and fish nutrition, poultry and fish 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, antimicrobial peptides, and probiotics with their role in poultry and fish industry instead of antibiotic growth promoters. This book provides detailed information about using antibiotics in the poultry and fish industry as growth promoters and developing bacterial resistance to antibiotics. All chapters give a holistic approach to how organic feed additives (herbal plants and their extracts, probiotics, peptides, *etc*.) can positively impact animal health and production. Also, the book chapters cover the main poultry species, including broilers, laying hens, quails, geese, ducks, turkey, and fish. This book will be useful for poultry and fish keepers and research in nutrition, pharmacology, and veterinary sciences.

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CHAPTER 1

Hazards of Using Antibiotic Growth Promoters in the Poultry Industry

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Abstract: The poultry industry is one of the significant hubs of the livestock industry and the world's largest food industry. In the last 50 years, it has become common to observe poultry antibiotic feeding to treat disease and growth. Antibiotics inhibit the growth of toxic and beneficial microorganisms. They are used as growth promoters when given in adjunctive therapy. The Centers for Disease Control and Prevention (CDC) estimates that fifty million pounds of antibiotics will be produced each year in the USA. Forty percent of the total antibiotics produced will be used in agriculture. 11 million pounds are used for the poultry sector and 24 million for domestic and wild animals. Ciprofloxacin, chloramphenicol, enrofloxacin, oxytetracycline, tylosin, tetracycline, virginiamycin, tilmicos, nitrofuran and sulfamids are used as growth promoters in the poultry industry globally. Antibacterial residues are found in various parts of poultry birds, *e.g.*, kidney, heart, gizzard, liver, chest, thigh muscles, albumin and egg yolk. These residues may directly or indirectly produce many health concerns in human beings, such as toxic effects in the liver, brain, bone marrow, kidney, allergic reaction, mutagenicity, reproductive abnormalities and gastrointestinal tract leading to indigestion. In addition, resistant strains of pathogenic microbes pose an indirect threat to antibacterial residues that can spread to humans and contaminate residual fertilizers used as plant fertilizers. This chapter describes the benefits and contraindications of

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antibiotics used as growth promoters and the toxic effects of antimicrobial residues in poultry and humans.

Keywords: Antibiotics, Feed, Growth, Poultry, Resistant.

INTRODUCTION

Growth-enhancing effects of in-feed antibiotics were recognized first in the 1940s when dried mycelia of Streptomyces aureofaciens were fed to animals containing chlortetracycline antibiotics [1]. Later, in 1946, Moore and his coworkers reported the growth-promoting effects of antibiotics in commercial poultry [2] that, opened a new era of antibiotics used in poultry feed. The use of antibiotics as a promoter of the growth in the poultry industry has been going on worldwide for over 50 years [1]. In 1981, the American Council for Agricultural Science and Technology published a report on antibiotics in feeding animals [1]. Though the report did not provide any data that the use of antibiotics in animals causes the emergence of resistant microorganisms that may produce drug-resistant infections in human beings, it started a debate on antibiotics in food animals. In 1986, Sweden was the first country that banned antibiotics for growth promotion [3]. Denmark in 1995 and European Union in 1997 banned the Avoparcin (an antibiotic growth promoter) in food-producing animals. Later, in 1999 European Union Commission banned other antimicrobials for use as growth promoters in farm animals [4].

Plenty of evidence establishes that the use of antimicrobials in farm animals for therapeutic purposes and/or growth promotion causes the creation of antibiotic-resistant bacteria in the environment that ultimately deteriorate the therapeutic options in human medicine [5 - 7]. About 7 million deaths in hospitals have been estimated due to antibiotic-resistant infections [8]. Antibiotics used in food-producing animals like poultry led to the transfer of resistant bacteria to human beings *via* animal food. These bacteria may further transfer resistant genes to the non-pathogenic commensal flora [9]. It is estimated that the antibiotics used in poultry are not completely metabolized in body tissues that accumulate in meat [10] and are also excreted into the environment *via* poultry droppings [11].

When poultry droppings are used as manure in agriculture fields, these antimicrobials enter the soil ecosystem and significantly alter the soil communities [12]. Moreover, when consumed by humans, crops/vegetables cultivated in such fields transmit antimicrobial-resistant genes to them [8, 13]. This chapter attempted to highlight the hazards of using antimicrobial growth promoters in the poultry industry. It will also illuminate the health risk of antibiotic's use and its residues in poultry products concerning the environment and human health.

ANTIBIOTICS AS GROWTH PROMOTERS

The mechanism of action of antibiotic growth promoters in poultry is illustrated (Fig. **1**). Antibiotics are growth-promoting drugs or chemicals that stop the growth of bacteria in low, sub-therapy doses [14, 15]. In recent years, antibiotics as growth promoters have increased dramatically due to increasing consumer demand for fast livestock and animal feed products. Microbial infections can reduce the growth and/ or yield of farm animals raised for food purposes; thus, controlling these infections by adding antibiotics to animal feed has been effective [16]. Antibiotics as growth promoters have several beneficial effects, such as efficient feed digestion in the animal body to achieve better feed-conversion ratios, which allow an animal to grow into a strong and healthy living being. In addition, the use of antibiotics in the feed may also help in controlling zoonotic infectious organisms at an early stage. In addition to the benefits of antibiotics as growth promoters, this practice involves many ecological and ethical concerns [17 - 19]. For example, antibiotics may be used as growth promoters and may not be cost-effective [20].

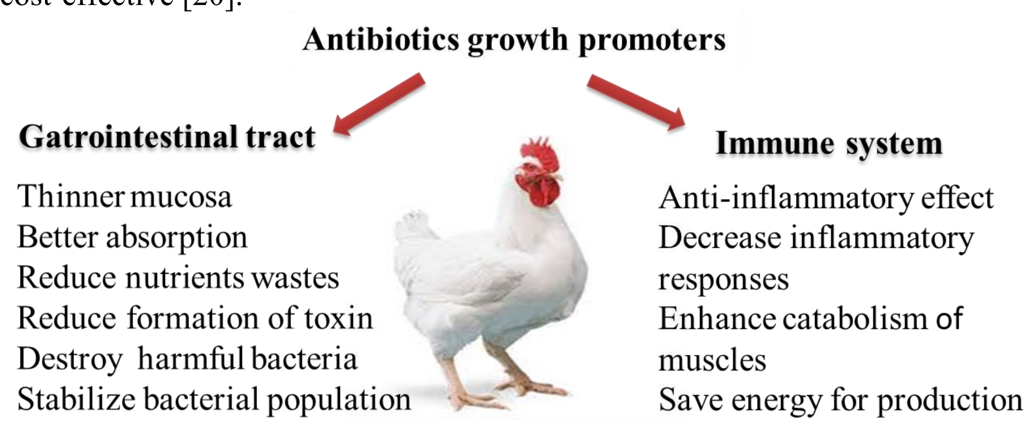

Fig. (1). Beneficial uses of antibiotic growth promoters in poultry.

In the 1950s, antibiotics used in domestic animals were introduced to fulfill the rapidly increasing food demand. Currently, some countries use antibiotics as growth promoters without strict regulation [21], while other regions and countries, such as Europe and America, prohibit their use as agricultural or growth promoters. However, antibiotics at therapeutic doses are allowed for prophylactic and preventive purposes. In fact, the United States (US) and many European countries are the main users of antibiotics in domestic food animals [22], whereas

CHAPTER 2

Herb and Plant-derived Supplements in Poultry Nutrition

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Abstract: Modern poultry industry faces the everlasting challenge of the growing demand for high-quality, low-priced food without compromising general hygiene, health, and welfare standards. To exploit optimal growth potential, antibiotic-supplemented feeds were implemented in the past decades. But later on, alternative strategies to trigger the productive characteristics of birds were proposed, including the use of phytochemicals. Phytobiotics are herbs and their derivatives, endowed with many beneficial effects. Herbs and their products enhance feed intake by mitigating intestinal damage, strengthening intestinal integrity, compensating nutritional needs for local and general immune response, reducing the concentration of pathogenic microflora, and preventing local inflammatory response. This form of feed manipulation recently gained interest in the poultry sector due to the lack of side effects, immune system modulation boosting, and stress tolerance. On the other hand, several types of research highlighted the potentially harmful effects of some herbs and their metabolites. This raised concerns among consumers about their safety and implications as feed supplements or medicines. This chapter will provide insights into phytobiotics, their role in immunity and growth, and the possible risks of herbal supplemented feeds in the poultry sector.

Keywords: Feed additives, Growth, Health, Herbs, Immunity, Poultry.

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INTRODUCTION

The use of antibiotics as growth promoters in animal feed leads to the inactivation of the immune system and poor antioxidant defense in poultry [3]. So, there is a need for alternative feed additives which can support the animal's growth without any side effects, *e.g.*, the antibiotic resistance of pathogenic microorganisms. For this purpose, the effects of probiotics, prebiotics, acidifiers, enzymes, and herbs on gut microbes have been studied in animals. Current antibiotic growth promoters (AGP) banned in poultry feeds increased the demand for numerous natural substances such as herbal medicines, and a new array of feed supplements for animal and poultry birds, which are useful due to their antimicrobial, antioxidant, and antifungal properties as well as immunomodulatory and anticoccidial effects [1].

Several medicinal herbs such as *Aloe vera*, Fenugreek, Ashwagandha, *Moringa oleifera*, Cinnamon, Tulsi, Garlic, and Pepper can be used as natural feed extracts in poultry. However, the types of effects produced by herbal preparations have not yet been determined. Generally, they are influenced by the concentration of active ingredients and the presence of supplementary substances and linkages with other active constituents of feed [2]. Herbs and herbal extracts have been used in poultry production for years to promote digestion [3, 4]. The multi-beneficial potential of bioactive components of green tea in poultry has also been assessed [5, 6]. These are natural substances, they are considered cost-effective, safe, and environmental friendly without any side effects. So, they are added to feed to improve birds' performance, feed utilization, health maintenance, and environmental stress-related effects. Several studies have reported the use of herbal derivatives in the diets of farm animals and poultry birds to improve the growth rate, gut integrity, nutrients adsorption, antioxidant activity and immunity and decrease diarrhea occurrence [4, 7]. As a result, these products are known as good alternatives to antibiotics to reduce their residues in milk, meat, and eggs [8]. Sometimes biological substances show different results in *in vivo* studies due to animal species, production stage, environmental condition, and features of the plant material used; hence, exhibiting the best results in young birds [9]. Among natural substances, essential oils showed great potential in poultry depending on the composition, type, origin, inclusion level, and the environmental condition of the trial [10 - 13]. For instance, cinnamon and a mixture of thymol and cinnamon have been reported to enhance the performance of broilers [10].

In contrast, cinnamon extract and oil enhanced bile production, reduced toxins, restored electrolytes, and improved digestion [13]. Moreover, curcuma alone or combined with *capsicum* increased resistance against intestinal disturbances such as coccidiosis and necrotic enteritis [11]. Besides essential oils, herbs also improved several functions in bird's body system, acting as sialogogues and allowing a more comfortable and easier swallowing. Extracts from *Salvia officinalis, Rosmarinus officinalis,* and *Thymus vulgaris* and the blend of carvacrol, capsaicin, and cinnamaldehyde enhanced feed digestibility in broilers [14]. At the same time, the main components of *Aloe vera,* including anthraquinones, saccharides, enzymes, vitamins, and low molecular weight compounds [17] are responsible for its immunomodulatory, anti-inflammatory, antiviral, wound healing, antitumor, antifungal, antidiabetic, and antioxidant effects [6, 15, 16, 18, 19].

The current chapter will focus on using herbs and phytochemicals in poultry nutrition as growth promoters and alternative sources to reduce the risk of antibiotic residues in poultry products.

PHYTOCHEMICALS

Phytochemicals, also known as phytobiotics or phytogenics, are natural derivatives of plants whose main bioactive components are polyphenols [11]. They can be added to animal feed to increase production and defend against infections, pests, stress, and physical damage [11]. Phytochemicals exist in solid, dried, and crushed forms or can be used as extracts categorized as oleoresins and essential oils based on the procedure used to obtain active ingredients [12].

However, phytochemicals also include other compounds like flavonoids, alkaloids, tannins, flavanones, and cyanogenic glycosides. The characteristics of flavonoids are broadly studied in animal experiments related to health status, protection against diseases, and food preservation strategies [20]. Flavonoids possess antioxidant, anti-inflammatory, and immunomodulatory properties [22]. In fact, they can increase mucosal and cellular immunity making them suitable to be added to feed to improve the health and immunity of broiler chickens. Phytochemicals exhibiting antioxidant properties have been documented as natural alternatives to artificial feed additives [21]. Moreover, some essential oils like thymol, carvacrol, cinnamaldehyde, and eugenol have also been used separately or combined with increasing animal production [11].

Beyond antioxidant properties, phytochemicals have also shown antimicrobial properties, so they can be added to feed to stabilize the intestinal microbes and decrease toxic microbial metabolites in the intestine. For instance, phytochemicals of *Allium hookeri* have been reported to improve the function of the gut barrier by improving gut proteins expression in the mucosa of young broilers [23]. *Moringa oleifera* leaves have strong prebiotic and antioxidant phytochemicals such as chlorogenic and caffeic acids [24]. Ginger and garlic can be the best substitute for artificial growth-promoting supplements such as antibiotics [25]. Ginger is used

CHAPTER 3

Ginger as a Natural Feed Supplement in Poultry Diets

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Abstract: Poultry ventures have progressed quickly over the last three decades. Therefore, curative or growth-promoting antibacterial agents have been utilized extensively. Because of increasing bacterial resistance towards antibiotics and, consequently, accumulation of antibacterial residues in chicken products and increased consumer's demand for products without antibacterial residues, alternative solutions that could substitute antibiotics without affecting productivity or product quality should be attempted. Recently, natural replacements such as ginger, etheric oils, organic acids, garlic prebiotics, immune stimulants and plant extracts were used to improve productiveness, and body performance, prevent pathogenic microorganisms, and reduce antibacterial activity usage in poultry manufacturing. The utilization of a single alternative or a combination of variable replacements and perfect surveillance and flock health might improve the profits and sustain the productivity of poultry. This chapter aimed at summarizing the recent knowledge and information regarding the utilization

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of ginger and its derivatives as natural alternatives or supplements in poultry feed and their impacts on poultry productivity, meat and egg traits in addition to economic efficacy.

Keywords: Antibacterial, Ginger, Meat quality, Natural alternatives, Poultry, Productivity.

INTRODUCTION

Nowadays, the uncontrolled usage of antibacterial antibiotics in poultry feed provokes serious complications. Many crucial reasons are found that forbid the utilization of antibiotics like drug residues in poultry meat and develop resistance of bacterial species against many drugs. Therefore, their usage has been controlled in different nations due to the spread of antibiotic-tolerant human pathogens [1 - 5]. The European Uniting Community firstly applied prohibition rules on using antibiotics in poultry feed in January 2006. However, the antibacterial administrated in sub-treating doses as antibacterial growth promoters had been separated [6]. To overcome the undesirable productivity and susceptibility to infections after removing antibacterial from poultry diets, attempts have been made to find other applicable replacements. Food additives might be nutritional or non-nutritional substances that control the nutritional substance availability in the diet. Natural growth promoters such as prebiotics, probiotics, enzymes, and botanical substances could be used as food supplements for broilers instead of synthetic types [7 - 9]. Recently, growth promoters like probiotics, yeast cultivations, organic acids, enzymes, prebiotics, plant-derived essential oils and some herbs' extracts have been utilized [10 - 16]. Ginger rhizome (*Zingiber officinale*) has been used as a remedy or tenderness seasoning. The ginger can be used as a substitute for antibacterial growth promoters due to increased poultry productivity, improved feed palatability and accessibility, and improved secretion of digestive enzymes [17]. Using antibiotics or synthetic supplements as food supplements in livestock feed is hazardous because of their potential toxicological properties. Besides, the tendency for using natural harvests has been increased to minimize the usage of synthetic components [18]. Therefore, therapeutic herbs or derivatives are believed to substitute synthetic compounds and achieve consumer demands and common market competition [19, 20].

Zingiber officinale Roscoe, relevant to the *Zingiberaceae*, generally known as ginger, is a monocotyledonous herbal plant and one of the chief common food-flavoring supplements globally [21]. Recently, several therapeutic effects of ginger have been recognized, for example, anti-inflammatory, analgesic, digestive moderating agent, antioxidant and antimicrobial properties [22]. Ginger might be a substitute for common synthetic growth promoters such as antibacterial agents

[23]. The characteristic ginger feel is derived from the unsteady materials that consist of zingerone, shogaols and gingerols [24]. This chapter highlighted the effects of ginger and its byproducts as natural supplements and feed additives on the poultry carcass characters, growth performance, egg and meat features, productivity, food digestibility, immunogenic reaction, some serum biochemical parameters, and bacteriological infection of poultry.

IMPACT OF GINGER OIL

Ginger oil has been derived from roots of *Z. officinale*, whose constituents are affected by the geographical zone, method of extraction and roots' status. Ginger oil's antibacterial, antifungal, analgesic, immunological, and anti-inflammatory effects have been preclinically studied [25]. Ginger oils have been well-studied and they are considered safe without detrimental effects. Owing to their broad pharmacological actions, their effects on digestive and respiratory diseases are of prodigious interest.

BIOCHEMICAL COMPONENTS OF GINGER EXTRACT

The biochemical constituents of ginger oil and its prospective antioxidant and anti-inflammatory effects have been studied [26]. By Gas Chromatography-Mass Spectrometry (GC–MS), ginger oil consists of zingiberene, which accounts for 31% of the total composition, curcumin represents 15.4% and sesquiphellandrene represents 14.02%. Ginger oil contains hydroxyl and α, α-diphenyl-β-picrylhydrazyl (DPPH) radicals and superoxide, which reduce fat peroxidation. Intraperitoneal injection of ginger oil causing the suppression of phorbol12-myristate-13-acetate commenced superoxide chemicals liberated by the macrophages. On the other hand, oral therapy of ginger oil for one month as a minimum definitively enhanced superoxide dismutase (SOD), glutathione and glutathione reductase levels [26].

According to the source of rhizomes, the product of ginger oil is changed from 1.0 to 3% [27]. Moreover, the origin of rhizome, freshness or dehydration, and extraction techniques affect ginger oils' chemical composition.

The basic ginger oil was extracted from fresh roots of *Zingiber officinale* by GC–MS [28]. The latter authors reported the existence of 69 elements, accounting for 96.93% of the total oil. The essential element was zingiberene representing 28.62%, followed by camphene representing 9.32%, curcumin representing 9.09% and lastly, β-phellandrene representing 7.97%. Examination of the oleoresin showed the presence of 34 constituents, calculating 88.63% of the total oleoresin. The main constituents were trans-6-shogaol representing 26.23%, trans-10-shogaol representing 13.0%, α -zingiberene representing 9.66% and 10-

CHAPTER 4

Use of Cinnamon and its Derivatives in Poultry Nutrition

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Abstract: The recent trend toward banning the use of antibiotics in poultry feed as a growth promoter directs the scientific community to look for natural alternatives with potential growth-promoting and immunomodulating properties. Phytogenic feed additives have attracted significant attention as alternatives to antibiotics to improve growth performance and enhance immune responses. They have anti-inflammatory, antioxidant, antiviral, and antifungal properties, depending on their chemical structure and composition. Scientists are using these non-conventional ingredients as feed additives in the form of oil or powder. Essential oils (EO) are volatile liquids produced from aromatic plants. Their application has gained momentum in controlling cholesterol as free radical scavengers, anti-microbials, antifungals, and stimulants of digestive enzymes. EO's possible antimicrobial features against harmful pathogens are primarily associated with the high content of volatile components in oils. The current chapter highlights the beneficial impact of cinnamon oil as a feed additive on poultry growth performance, meat quality, carcass traits, and its hypo-cholesterolaemic impact, antioxidant act, microbiological aspects, and immunomodulatory effects.

Keywords: Cinnamon, Essential oil, Hypo-cholesterolaemic property, an antibiotic alternative, Poultry.

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INTRODUCTION

The poultry industry is the largest food-providing sector globally, and it is considered one of the primary livelihoods of rural communities [1]. According to many research data, it is proved that the dietary combination of natural products containing bioactive components and poultry products may beneficially impact human health [1, 2]. Essential oils derived from different plant parts are frequently used in cosmetics as a lush fragrance, skincare, and herbal perfumery. They are also used for medicinal purposes as potent antifungals that can possess inhibitory effects against harmful pathogens [3, 4].

Moreover, these natural herbs have gained much attention as growth promoters in today's poultry production because of their pronounced effects on birds' health and performance. These herbs and their derived products are replacing antibiotic growth promoters (AGP) to some extent. Besides, their local and economic availability makes them more precious as natural feed additives for the poultry industry. Apart from these beneficial effects, they positively impact digestion and absorption processes [5]. Recently, various herbs and extracts have been used to increase birds' overall productivity. Cinnamon essential oils (CEOs) and their major compounds have strong antibacterial effects against *Escherichia coli, Parahemolyticus, Staphylococcus epidermis, Enterococcus faecalis, Pseudomonas aeruginosa, Staphylococcus aureus,* and *Salmonella sp* [6].

Furthermore, diets fortified with cinnamon and its extracted oils have inhibitory effects against pathogenic bacteria and improve poultry performance by enhancing their digestive capacity [7]. The observation recorded by another study [8] indicated that cinnamon and its oil also have potent analgesic and hypocholesterolemic properties and may serve as strong free radical scavengers. This chapter describes the beneficial applications and new aspects of cinnamon and its derivatives, which will be valuable for physiologists, scientists, nutritionists, veterinarians, pharmacists, pharmaceutical industries, and poultry breeders.

CHEMICAL COMPOSITION

Various scientific reports have been published on quantifying and identifying compounds present in cinnamon. The essential volatile oil of cinnamon (CEO) is mainly obtained from its bark and leaf. The concentration of some cinnamon oil constituents is presented in Table **1**. The chemical constituents of CEO are immensely varied among the different plant parts, such as (roots, leaves, bark, and fruit). Moreover, the oil extraction method also influences its production. The essential oil of the bark of *Cinnamomum altissimum Kosterm* contains important compounds like α-terpineol (7.8%), methyl eugenol (12.8%), linalool (36.0%), and limonene (8.3%). The whole phenolic constituents represent about 50 µg GAE/mg oil. Also, the extract's antioxidant action was 345.2 µM Fe^{+2}/g dry mass using ferric reducing antioxidant power assay (FRAP) and with a concentration of IC50 of 38.5 µg/mL by the method DPPH (1,1-diphenyl-2-picrylhydrazyl) assay. It was observed that *Cinnamomum verum* leaf oil has an optimum volatile component (3.23%) [8].

Table 1. Some chemical constituents are identified in the cinnamon oil (leaf and bark).

Compound	Concentration (%) in Cinnamon Leafoil	Concentration (%) in Cinnamon Bark Oil
Eugenol	74.9	0.39-2.37
Benzaldehyde	0.1	0.23-0.31
Benzyl benzoate	3.0	0.01-0.37
Benzyl alcohol	0.2	0.14
Caryophyllene oxide	0.5	0.35
Cinnamaldehyde	1.1	62.09-89.31
Cinnamyl acetate	1.8	1.48-2.44
1,8-Cineole	0.6	1.02
Camphene	0.3	0.08-0.12
Linalool	2.5	1.6-4.08
α-Pinene	1.2	0.37-0.50
β-Phellandrene	0.2	0.23-0.25
α-Cubebene	0.9	0.12-0.21
Limonene	0.5	0.19-0.33
Cymene	0.8	0.02-1.31
α-Humulene	0.6	0.01-0.28
Myrcene	0.1	0.05-0.40
β-Pinene	0.3	0.07-0.15
Delta-3-Carene	0.6	0.37
β-Caryophyllene	4.1	0.89-2.05
Phenylethyl alcohol	0.1	0.15
α-Terpinene	0.1	0.03
α-Phellandrene	0.9	0.01
α-Terpineol	0.3	0.01
α-Thujene	0.2	-
Safrole	1.3	-

CHAPTER 5

Clove (*Syzygium aromaticum*) and its Derivatives in Poultry Feed

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Abstract: Production of safe and healthy poultry diets of high profitability is the central aim of poultry men. This safety is achieved by using natural products as growth stimulants. Natural feed additives such as medicinal products derived from herbs and spices are mainly used in the poultry feed industry as appetite and enzyme secretion stimulants. The use of clove (*Syzygium aromaticum*) and its derivatives has lately received much greater attention as an alternative to traditional antibiotics. The clove exhibited strong antibacterial, antioxidant, anti-septic and anti-inflammatory properties and appetite and digestion stimulants. The clove and its derivatives contain bioactive components, including eugenol, eugenyl acetate, β-caryophyllene, salicylic acid, ferulic acid, caffeic acid, ellagic acid, kaempferol, methyl amyl ketone, humulene, gallotannic acid, and crategolic acid that have beneficial effects. Eugenol is the main bioactive component present in the clove. The potential advantages of utilizing clove extracts in poultry diets include improved growth performance, egg production and feed conversion ratio, enhanced digestion, and down-regulated disease incidence. From the available literature, clove and its essential oil is one of the beneficial plant extracts to increase growth performance in poultry by improving the intestinal microbiota population. Clove extract contains various molecules (principally eugenol) that have self-biological activities in poultry physiology and metabolism. This chapter includes information on clove and its derivatives in poultry nutrition.

Keywords: Antibacterial, Antioxidant, Clove, Eugenol, Poultry nutrition.

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INTRODUCTION

The clove (*Syzygium aromaticum,* Fig. **1**) is a precious, valuable, and important spice of the family *Myrtaceae* used as a food preservative and its medicinal benefits are known for centuries. Clove has a historical background and is believed to be originated in the 1st century BC [1]. Its unique odor and sweet taste are commonly used as a spice worldwide [2]. For the growth of clove, well-drained, organic matter-rich loam soil is required. The optimum temperature required for clove growth is 20-30ºC, whereas above 10ºC constant temperature is vital for it. This specie barely tolerates the waterlogged soggy conditions. The geographical area with 150-300 cm rainfall is considered for its growth [2]. It has a good concentration of fiber and minerals like magnesium, potassium and calcium. The clove also has a high concentration of manganese [3]. Besides, the clove is also a good source of omega-6 fatty acids.

Fig. (1). Clove (*Syzygium aromaticum*).

Clove is an important source of various phenolic compounds, including hydroxybenzoic acid, hydroxycinamic acids and hydroxyphenyl propenes. Eugenol is the main bioactive component in the clove, present in a concentration of 9381.7 to 14650 mg/100 g of fresh plant weight. Gallic acid is also found in a 783.5 mg/100 g fresh weight [4]. Around 25 to 20% volatile oil is present in good quality oil containing 70-85% eugenol, 10-15% eugenol acetate and 5-12% beta-caryophyllene. Some other constituents are responsible for the characteristic and pleasant fragrance. However, these constituents are present in minor quantities and include kaempferol, methyl amyl ketone, α-humulene, β- humulene, gallotannic acid, methyl salicylate, benzaldehyde and crategolic acid [5]. Some other phenolic acids present in the clove are salicylic acid, ferulic acid, caffeic acid and ellagic acid, whereas flavonoids are present in trace amounts, including kaempferol and quercetin. Appreciable amounts of essential oil are present in aerial parts of clove [5 - 10].

One of the main phytochemicals present in the clove essential oil (CEO) is eugenol and shows bactericidal action by increasing the permeability of the cell membrane and burst of the cytoplasmic membrane. The CEO and eugenol have antibacterial potential against gram-negative bacteria like *salmonella Typhimurium, salmonella enteritidis, E. coli* and *Pseudomonas aeruginosa,* and gram-positive bacteria like *Listeria monocytogenes, streptococcus pyogenes, streptococcus pneumonia, staphylococcus aureus, staphylococcus epidermis, Bacillus subtilis* and *Bacillus cereus* [11 - 13]. Researchers have reported the antiviral activity of clove, where Eugenin that is isolated from CEO exhibited an inhibitory response (dose: 10 µg/ml) against the herpes simplex virus [14]. Similarly, researchers found that administering eugenol (intravenous and intragastric route) in rabbits compared to paracetamol showed greater fever-reducing potential [1]. The clove and its derivatives are found to be active against fungi. They act as fungicide agents by increasing the cell permeability and altering the cell morphology of the different fungi, namely, *Aspergillus species, Candida albicans, Dermatophyte species, Epidermophyton floccosum, Fusarium moniliforme, Fusarium oxysporum, Mucor species, Microsporum canis, Microsporum gypseum, Trichophyton mentagrophytes, Trichophyton rubrum* [15 - 17]. The main objectives of the following sections are to provide an overview of the use of clove and its derivatives in poultry feeding. Lastly, the nutritional value of the clove plants and their effect on immunity, performance, and other health aspects will be very valuable for physiologists, scientists, nutritionists, veterinarians and pharmacists.

NUTRITIVE VALUE OF CLOVE

The clove (*Syzygium aromaticum*) is a precious, valuable, and important spice of *Myrtaceae*. Due to its unique odor and sweet taste, the clove is commonly used as a spice worldwide [2]. Besides its taste and odor, clove is rich in nutrient content. The nutrient composition may vary in different parts of the world due to the agro-climatic conditions under which cloves are cultivated and the various methods used to process and prepare these dried clove buds [18]. The clove contains good fiber, magnesium, potassium and calcium. The clove also has a high concentration of manganese [3].

Additionally, clove is also a good source of omega-6 fatty acids. According to the US Department of Agriculture, the clove contains 9.87% moisture, 5.97% protein, 65.53% carbohydrates, 33.9% dietary fiber, 13% lipids, and 5.67% ash contents. The detailed nutrient composition of the clove is given in Table **1**.

CHAPTER 6

Pomegranate (*Punica Granatum* L): Beneficial Impacts, Health Benefits and Uses in Poultry Nutrition

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Abstract: *Punica Grantum* L is an ancient, magical and distinctive fruit. It is local to the Mediterranean basin and has been broadly utilized in traditional pharmaceuticals in numerous nations. The extracts collected from various parts (peels, seeds, juice and flowers) of this natural fruit can be used as multiple additives for practice because of its polyphenolic contents. Polyphenols found in *P. Grantum* have been shown to have

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various pharmacological activities such as anti-inflammatory, antioxidant, antimicrobial, anti-diarrheal, immunomodulatory, anti-carcinogenic, and wound healing promotors. Moreover, they are reported to have anti-cestodial, anti-nematodal and anti-protozoan activities. *P. Grantum* L or its by-products supplementation can play a major role in poultry nutrition by enhancing immunity, scavenging free radicals, and inhibiting antimicrobial activity, leading to improved poultry performance. Owing to its functions above, it can be a potential substitute for modulating immune functions and gut microbiota to relieve diarrhea and enteritis, preventing colibacillosis and coccidiosis in chickens. Moreover, it is reported that polyphenols and tannins of *P. Grantum* act as an antioxidant by scavenging reactive oxygen species and preventing lipid oxidation and inflammatory molecule production. This chapter highlights the work done in the recent past on *P. Grantum.* Despite the voluminous pharmacological properties of *P. Grantum,* its usage in the chicken ration is limited. So, this chapter aims to broaden the information of researchers, veterinary advisors, and poultry nutritionists to recommend *P. Grantum* as a safe, natural added substance in poultry feed to substitute the synthetic additives for nourishment purposes.

Keywords: Chicken, Growth performance, Immunity, *Punica granatum* L. by-products.

INTRODUCTION

Currently, traditional medicinal plants for health care have gained great worldwide attention. Phytobiotics, natural bioactive compounds derived from plants, are mainly flavonoids, alkaloids, tannins, terpenes, steroids, and essential oils [1, 2]. Recently, phytobiotics have been considered antimicrobial growth promoters due to their antimicrobial, immunomodulatory, and antioxidant activities [3, 4]. At present, the European Union has restricted antibiotics supplementation in poultry production due to concerns about bacterial resistance in humans. Consequently, poultry nutritionists and researchers are pursuing alternative feed additives for commercial poultry species to improve their productivity *via* maintaining gut health and improving the feed utilization and quality of products obtained from these birds [5, 6]. Recently, herbal plants, powders, and extracts have been used as alternative feed additives in many poultry studies [7 - 10]. Pomegranate, a fruit from the Punicaceae family, has been used for various purposes, commonly eaten raw, served as a drink, used in the cocktail and ground after drying and used in traditional recipes. Besides, it is used in the food, dyes and cosmetics industry [11, 12].

Additionally, to eliminate environmental pollution, discarded parts (peels, rinds and seeds) of the pomegranate can be a nutritious feed additive for animals [13] and poultry. Pomegranate is enriched with several phytochemicals, mainly polyphenols [14]. Its peels accounted for about half of its weight. They were reported to contain several phenolics, tannins (ellagitannin, pedunculagin, punicalagin and punicalin), flavonoids (kaempferol, quercetin and luteolin glycosides) and phenolic acids (caffeic acid, coumaric acid, chlorogenic acid, phlorodizin, rutin and ferulic acid) [15, 16]. Arils also contain many polyphenols, such as gallic acid, chlorogenic acid, catechin, ferulic acid, coumaric acid, and caffeic acid [17]. In *in vitro* investigations reported an antimicrobial capacity of pomegranate peel and seed owing to their phenolic contents [18, 19]. The health benefits of pomegranate are innumerable. Oral administration of pomegranate peel powder enhances humoral and cellular immunity [20].

Additionally, pomegranate extract has anti-inflammatory, antioxidant, anti-cancer, cardio- and neuroprotective effects [21] and enhances wound healing [22, 23]. Pomegranate peel extract is effective against different types of bacteria [24, 25]. This effect is owed to its polyphenol content [15, 26]. Also, the oil content of pomegranate seed is rich in an immunomodulatory compound, punicic acid [27]. Several properties of pomegranate are beneficial and further studies concerning its use in poultry nutrition are needed. The use of pomegranate peel has no growth-promoting effect in broiler chickens [28]. After an extensive review of literature, it is established that various parts of pomegranate (juice, bark, seeds and leaves) have gained concern and studied in different animal species. Despite the exciting advantageous capacities of pomegranate, many investigations of its applications in poultry nourishment are needed. So, this reappraisal aims to provide a modern understanding to veterinary analysts and poultry nutritionists to conduct more inquiries about pomegranate to assess its utilization as a safe, natural feed additive in poultry feed.

PHYTOCHEMICALS IN POMEGRANATE

In the last few years, substantial advancement has been made to understand pomegranate's mechanisms and pharmacological mode of action. Individual parts (roots, bark peels, rind, seeds and leaves) have their own medicinal and therapeutic benefits. The most therapeutically valuable phytochemical constituents of pomegranate are anthocyanins, anthocyanidins, ellagic acid, ellagitannins, punicic acid, flavonoids, estrogenic flavonols and flavones. Important phytochemical constituents of pomegranate and their structures are presented in Table **1** and Fig. (**1**).

Table 1. Principal phytochemical constituents of pomegranate.

Plant Component	Phytochemical Constituents
Pomegranate Juice	Anthocyanins, caffeic acid, glucose, ellagic acid, ascorbic acid, gallic acid, catechins, rutin, quercetin [29 - 32]
Pomegranate seed oil	Punicic acid, ellagic acid, sterols, fatty acids [33, 34],

CHAPTER 7

Use of Chicory (*Cichorium intybus*) and its Derivatives in Poultry Nutrition

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Abstract: Chicory (*Cichorium intybus*) is a perennial herb that belongs to the Asteraceae family. Certain species are grown and used as fried, dry salad leaves, roots, or chicons as a substitute for coffee additives. It is also cultivated as forage that can be used in animal feeding. In addition, chicory has significant effects on animal and human health and has various biological activities, such as immunostimulant, antimicrobial, antioxidant, hyperlipidemic, anti-inflammatory, and antidiabetic activity. Chicory extracts protect the liver by lowering the levels of liver enzymes, *e.g*., aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP). The chicory plant plays a key role in protecting hepatocytes and other liver cells. It is used as an antimicrobial agent *in vitro* and *in vivo* against certain pathogenic bacteria species. Chicory improves immunity and feed efficacy by reducing pathogenic microorganisms in the gastrointestinal tract. *Cichorium intybus* roots were also used to alleviate slight intestinal disturbances, including the sense of flatulence, full abdomen, transient appetite loss, and indigestion. This chapter describes the role of chicory plants in promoting growth when used as feed additives in poultry feed. It also explains the mechanisms of action of chicory extracts and their role as a liver protector for poultry.

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Keywords: Antioxidant, Aspartate aminotransferase, Hepatocytes, Indigestion, Protection.

INTRODUCTION

Synthetic antibiotics are used worldwide as feed additives regardless of their adverse effects on animals and humans. Since the European Union banned antibiotics as growth promoters in 1999, the quest for alternatives has been a major focus of the scientific investigation. Thus, the use of herbal feed additives is becoming more popular in animal production due to the restriction on certain antibiotics [1, 2]. Chicory (*Cichorium intybus*) is among many herbal plants that could be used in poultry feed as a natural feed additive. Because the poultry industry is one of the most extensive industries that satisfy the protein demand of consumers, the world's impressive development of the poultry industry has been attributed to the control of diseases, feed processing and genetic and managerial modifications. Diverse approaches have been employed to boost broiler efficiency in production, feed utilization and economy. Among these methods, the most used method is antibiotics usage as a growth promoter [3]. For certain countries, antibiotics used as a feed supplement were prohibited because of severe food insecurity since these antibiotics provide resistance to several bacteria in animals and humans. The demand for antibiotic-free poultry meat increases daily as we recognize the negative effects of antibiotics on human health. In addition, other factors such as technology and science advancement, hygiene, and improvements in nutrition regulation play a significant part in growing the market for healthy foods. Nowadays, poultry experts look forward to discovering other antibiotic alternatives to mitigate the health problems in poultry and consumers and boost immunity and the consistency of feed by reducing gastrointestinal tract pathogenic bacteria [4].

Various sections of herbal medicinal plants and herbal derivatives, including black cumin [5], derived products from quercetin [6] and chicory, have been used as growth promoters for poultry feed but with differing results [7, 8]. Such plants contain several properties, including growth promoters, antibacterial, antifungal, anticancer, anti-malarial, anticoccidial, gastroprotective, diuretic and immuno-stimulant. Nonetheless, a few experiments indicated a lack of knowledge on chicory use for hepatoprotection and the core mechanism for the positive effects of chicory in poultry production. Therefore, this work aims to shed light on this therapeutic herb to alleviate liver damage and substitute chicory antibiotics eventually and have future hope in the poultry industry [9].

THE DESCRIPTION OF PLANTS AND THEIR CHEMICAL COMPOSITION

Chicory is a perennial herb that belongs to the Asteraceae family (Table **1** and Fig. **1**).

Table 1. Scientific classification of chicory herb.

Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Asterids
Order:	Asterales
Family:	Asteraceae
Tribe:	Cichorieae
Genus:	Cichorium
Species:	C. intybus
Binomial name	*Cichorium intybus*

Fig. (1). Chicory herb, root and dried root.

It is habitually grown with other plants such as lucerne and berseem (Fig. **2**) [10]. It has multiple applications in manufacturing and can be used as an antimicrobial and antioxidant agent in poultry [11, 12]. Compared to the therapeutic elements, kasni's nutritional profile is also good as it includes some quantities of vitamins and minerals (especially vitamin C). Different active component forms include carbohydrates (fructose, mannitol, and lactose), micro-minerals, and vitamins (Fig. **3**) [13 - 15].

CHAPTER 8

Use of Psyllium Husk (*Plantago ovata*) in Poultry Feeding and Possible Application in Organic Production

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Abstract: Herbs or medicinal plants have gained significant attention due to their bioactive compounds that could act as antioxidants, anti-inflammatory, antimicrobial, anticancer agents, *etc*. Psyllium husk (*Plantago ovata*) is an Indian native herb. The water-loving (hydrophilic) mucilloid and water-soluble fiber derived from *Plantago ovata* have been used in traditional Indian Ayurvedic medicine as a crucial remedial mediator of constipation. Psyllium is a rich source of fiber and has many other remedial properties, including lowering the level of cholesterol, raising energy, relaxing inflammation, serving as an antidiarrhoeal, antidiabetic, laxative, and also used in hemorrhoid therapy, and as weight loss agent. The blood serum cholesterol-lowering property of the psyllium husk had drawn the researchers' main focus; thus, Psyllium is

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thought to be a plausible herbal agent helpful in treating hyperlipidemia. In various animal models, cholesterol levels are reduced by binding Psyllium husk with bile acids in the intestinal, thereby lowering its absorption rate. Screening literature has demonstrated that Psyllium husk could be utilized as an antidiarrheal mediator to cope with the diarrheal symptoms associated with poultry farming disorders. Additionally, Psyllium may also benefit various poultry species' production and growth traits. The present chapter explored Psyllium's potential responsibility for coping the hypercholesterolemia and the uses of psyllium husk as a safe feed additive in poultry farming for organic production and lowering cholesterol in meat and for production of functional foods.

Keywords: Dietary fiber, Growth, Hypocholesterolemic, Poultry, Psyllium.

INTRODUCTION

Herbal plants are recognized as an indispensable share of traditional medicine due to their phytochemical constituents. Improvements were noticed in the growth performance of birds by the dietary inclusion of several herbal plants. Antibiotics as growth agents in poultry and livestock production have been significantly limited in many countries over the past several decades. Consumers are now aware of the prevalence of antibiotics in meat and eggs and need natural foods such as plant products as substitutes. The application of herbal materials and their derivatives as growth promoters is most widely used worldwide to boost poultry and livestock productivity [1 - 5]. Several investigations have been recommended using various medicinal plant sources or their derivatives as natural feed supplements in different poultry and livestock systems [6 - 11]. Psyllium (*Plantago ovata*), an Indian native plant known as isapgol/ispaghula [13], belongs to *Plantaginaceae*. Since prehistoric times, it has been used as a traditional herbal medicine in ayurvedic and allopathic treatments [12, 13]. Its seed and husk contain high water-soluble hydrophilic mucilloid fiber levels in various primary and secondary metabolites and bioactive components [14]. In India, one of the most crucial principle producers of *Plantago ovata* is present and widely grown in various subtropical and tropical areas like China, India, Egypt, Iran, Japan, Korea, *etc* [15].

Dietary fiber and its fractions are among the different nutraceutical essential foods that have earned the most importance over the last few decades. Consumption of dietary fiber foods has been documented to boost the long-term maintenance of down atherogenic Low Density Lipoprotein (LDL)-cholesterol [13, 16]. According to the American Heart Association's advice, dietary fiber and other lifestyle practices could decrease the peril of cardiovascular ailment. They suggested augmenting the soluble fiber level in the diet to more than 25 g / d to effectively reduce total cholesterol and LDL levels [17].

Psyllium husk is generally utilized as a sedative agent [18], which reduces the concentration of serum cholesterol and LDL in hypercholesterolemic children and adults [18 - 24], raises the levels of High Density Lipoprotein (HDL) cholesterol, as well as reduces the level of glucose in diabetic patients [18]. Also, it has been suggested as a useful dietary assistant for psychotherapy in reducing total and LDL-cholesterol levels in adults [19], specifically those who do not respond effectively to low-fat cholesterol and low-fat diets [20]. Many reported studies on different animal models, including humans, have confirmed Psyllium hypocholesterolemic therapy claims [24, 25].

The water-soluble dietary fiber is an effective therapeutic agent as a functional nutritional product against various ailments such as physiological diabetes mellitus, obesity [26], diarrhea [27], constipation [28], intestinal inflammation [29], cardiovascular diseases [30], hypercholesterolemia [31], and also act as prebiotic [32] and antioxidant [33]. The pharmacological and therapeutic activities of psyllium polysaccharides have been thoroughly investigated by Madgulkar *et al.* [34].

Chicken eggs are a vital part of the human diet and are considered healthy food with high-quality protein [4]. Since chicken eggs have a high cholesterol level (about 213-280 mg), health consultants are frequently advised to reduce the consumption of eggs from regular diets, especially for individuals with hyper-cholesterol-related syndromes [35]. Besides, customers are hesitant to embrace its benefits because they have concerns about its high cholesterol content, which affects their health. Scientists are now searching for new strategies to supply functional eggs with lower cholesterol concentrations [36]. The addition of psyllium husk in poultry diets is a successful technique to minimize cholesterol in the blood serum and egg yolk [37]. Several dietary fiber items are currently introduced into poultry diets to reduce the cholesterol levels in eggs. The present work aimed to address psyllium fiber as a beneficial agent for lowering serum total cholesterol and serum-LDL-cholesterol and egg or meat in poultry, its essential component in organic and low-cholesterol egg and meat for functional foods.

Geographical Source of Psyllium

The morphology of the psyllium plant is presented in Figs (**1** and **2**).

Psyllium is cultivated in several parts of India, including Maharashtra, Rajasthan, Punjab, and Gujarat, while in Pakistan, it is found in Sindh and West Pakistan [38]. It is also grown in European countries such as France and Spain to cover the European market requirements. The seeds are produced all over Southern Europe and North Africa [38, 39]. Psyllium husk is used as industrial powders distributed

CHAPTER 9

Dandelion Herb: Chemical Composition and Use in Poultry Nutrition

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Abstract: *Taraxacum officinale,* also known as dandelion herb, is a popular medicinal and therapeutic herb used for many years and is mostly raised in Europe, Asia, North and South America. It contains several nutrients and bioactive substances, especially the leaves and roots of this herb, which are a rich source of fiber, lecithin, choline, and micronutrients such as minerals (potassium, magnesium, calcium, zinc, *etc*., iron) and vitamins (A, C, K, and B-complex). The root has been commonly used for digestive and liver problems due to its stimulatory effects on the production of bile and detoxification functions. The leaves of dandelion have stimulatory functions on the digestive system and possess diuretic effects. Furthermore, several studies have shown that dandelion leaves can enhance the growth and productivity of poultry. Various functions on the intestinal mucosa have been reported, including the effects on the architecture of villi, villus height/crypt depth ratio, and cellular infiltration. This herb also has various beneficial functions, such as immunomodulatory effects, stimulation of the digestive system and insulin activation, enhancing the metabolism of androgens, and acting as a probiotic, antiangiogenic, antineoplastic and demulcent. Moreover, the dandelion herb can treat indigestions and hepatitis B infection. Due to the lack of

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studies on the effects of dandelion, further research has to be conducted to exploit the medicinal properties of this herb for its beneficial health impact on humans, pet and livestock animals (*e.g*., poultry) nutrition.

Keywords: Beneficial effects, Chemical composition, Dandelion, Pharmaceutical, Poultry.

INTRODUCTION

Recently, therapeutic herbs are becoming increasingly popular worldwide for their medicinal and health-promoting properties in humans and animals, particularly poultry [1 - 5]. This review focuses on the medicinal plant known as dandelion (*Taraxacum officinale*). Dandelion, a perennial plant, belongs to the Asteraceae (Compositae) family. Dandelion is commonly utilized in several conventional and current herbal therapeutic procedures, especially in Asia, North America, Africa and Europe [6 - 10]. It is described as a weedy species and can be found in various climatic conditions, on roadsides, shores and areas where the soil is moist [11]. Dandelion is known in English terms as Blowball, Swine's snout, Cankerwort, Lion'stooth [12] and Arabic terms like Khas Berri and Hindiba [13]. The Latin name for dandelion is *Taraxacum*, which could be a derivate of the Arabic word "Tharakhchakon" [11] or the Greek word "Tarraxos" [13]. However, the most common name for this herb is "Dandelion", which originates from the French expression "Dent de lion", meaning "Lion's tooth", due to the serrated leaves of this plant [13]. The root of the dandelion has been most commonly used in digestive disorders, promoting the digestion process and functions of the liver, while the leaves have diuretic and gastrointestinal effects [14]. Although not all researchers agree, several studies have pointed out numerous beneficial effects of dandelion, including immunomodulatory, digestion, and insulin stimulation. It has been proven to have probiotic, demulcent, antiangiogenic, and antineoplastic functions [8, 15]. As previously mentioned, Dandelion has been used for decades as a traditional therapeutic herb due to its various medicinal properties, especially in Chinese traditional medicine. From the pharmacological point of view, the effects of dandelion are due to the presence of some bioactive substances, like flavonoids, tannins, saponins, lactones, and alkaloids [8, 15, 16]. Williams *et al.* [17] have isolated several flavonoids from dandelion, including caffeic acid, chlorogenic acid, luteolin, and luteolin 7-glucoside. The leaf of dandelion contains fibers, proteins, minerals such as calcium, phosphorus, potassium, magnesium, iron, and vitamins including A, C, and B-complex [18, 19].

A ban on antibiotics as feed additives in poultry nutrition is realized because of the increased occurrence of pathogens resistance against therapeutic antibiotics used in poultry nutrition [20, 21]. Due to the limited usage of antibiotics in diets, efforts are being made to find alternative strategies to enhance the health status, growth performance, boost immunity, and increase the productivity and economic benefits of poultry farms [22 - 24]. A plausible solution to these problems could be the more frequent use of phytogenics, a group of natural growth promoters and antimicrobial agents, in herbs, plant extracts, cold-pressed or essential oils and phytochemicals [23, 25 - 27]. Such supplements are added to the diets of poultry to raise the productivity and economic feasibility by enhancing digestibility, bioavailability and absorption of nutrients while at the same time eliminating pathogenic microorganisms from the gastrointestinal system [1, 28, 29]. Showing very promising results, dandelion is one such phytogenic agent, which could have beneficial effects when supplemented with poultry diets [10, 30 - 32].

Structure and Chemical Composition

Generally, the dandelion herb is cultured mainly in India, and its rhizome, root and leaf have a wide application in medicine. The major components in dandelion are sesquiterpene lactones (having anti-cancer anti- and inflammatory effects) [33, 34], phenylpropanoids (which are not toxic and have analgesic, anti-inflammatory, and hypotensive functions), polysaccharides, and triterpenoid saponins.

The main sesquiterpene lactones that are commonly existing, include glycosides, containing taraxacolides, dihydrolactucin, ixerin, ainslioside, taraxacosides, and taraxinic acids. As a part of the sporopollenin structure, phenylpropanoids are plentifully present in dandelion herb and consist of several bioactive acids such as inulin, caffeic acid, cichoric acid, chlorogenic acid, monocaffeoyltartaric acid, and 4-caffoeylquinic acid, (a class of fibres known as fructans) [7, 8, 15, 35]. The root of the dandelion herb is a rich source of triterpenes, including taraxol, taraxerol, taraxasterol, β-amyrin; ψ-taraxasterol, sterols (stigmasterols, β-sitosterol) and inulin [7, 36, 37]. The stem, root and flower of dandelion contain high concentrations of flavonoids, saponins, tannins, alkaloids and phenols, whereas flower extracts have the highest concentration of flavonoids [13, 16, 38]. Furthermore, phenols and steroids are also represented [7]. This herb is a very rich source of minerals, such as calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), iron (Fe), zinc (Zn), and copper (Cu) [13, 39, 40]. Besides, macro- and micro-elements, the leaf of dandelion contains higher concentrations of β-carotene compared to carrots and greater amounts of Fe and Ca in comparison to spinach [39]. Qureshi *et al.* [41] reported that dandelion contains 90.66% dry matter, 13.81% crude fibre, 11.40% crude protein, 9.34% moisture, and 3.3% ether extract. The mineral composition of dandelion contains Ca, Mg, Na, Cu and Zn as 7.3, 2, 0.013, 0.05 and 0.14 mg per 100 g, respectively [40].

CHAPTER 10

Probiotics in Poultry Nutrition as a Natural Alternative for Antibiotics

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Abstract: Since the early 1950s, antibiotics have been used in poultry for improving feed efficiency and growth performance. Nevertheless, various side effects have appeared, such as antibiotic resistance, antibiotic residues in eggs and meat, and imbalance of beneficial intestinal bacteria. Consequently, it is essential to find other alternatives that include probiotics that improve poultry production. Probiotics are live microorganisms administered in adequate doses and improve host health. Probiotics are available to be used as feed additives, increasing the availability of the nutrients for enhanced growth by digesting the feed properly. Immunity and meat and egg quality can be improved by supplementation of probiotics in poultry feed. Furthermore, the major reason for using probiotics as feed additives is that they can compete with various infectious diseases causing pathogens in poultry's gastrointestinal tract. Hence, this chapter focuses on the types and mechanisms of action of probiotics and their benefits, by feed supplementation, for poultry health and production.

Keywords: Growth promoters, Health benefits, Nutrition, Poultry, Probiotics.

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INTRODUCTION

Eight decades ago, antibiotics were used as growth promoters in the animal's diet, when it was observed that supplementation of *Streptomyces aureofaciens* harbor chlortetracycline residues in the bird or animal's feed increased their growth rate [1]. Nevertheless, microbial resistance to antibiotics that used for the treatment of diseases has emerged, destruction of beneficial microbiota in the gut was observed, as well as reduced growth rate has resulted from the use of antibiotics as feed additives which may be due to the increasing incidence of subclinical necrotic enteritis [NE] and dysbacteriosis [2]. Hence, European Union [EU] has prohibited using antibiotics as growth promoters or food additives since 2006.

According to the Organization of Food and Agriculture and the Economic Co-operation and Development Organization, the global meat consumption by 2023 was estimated to be an average 36.3 kg in retail weight, a 2.4 kg increase from 2013. Furthermore, around 72% of the increased meat consumption is expected to be obtained from poultry. Chicken is the most nutritious, low-priced, low in fat, adjustable, and high-quality protein source [3], and therefore, the demand for antibiotic-free poultry is increased. Research works are interested in providing alternatives like avian egg antibodies, cytokines, toll-like receptors, probiotics, and others for growth-promoting, preventing diseases, and stimulating the host immunity [4, 5].

Probiotics are defined as "Live strains of strictly selected microorganisms which, when administered in adequate amounts, confer a health benefit on the host" [6]. Also, Abd El-Hack *et al.* [7], defined probiotics as "live microbial feed additives which beneficially affect the host animal *via* enhancing the balance in the gut and consequently improving feed efficiency, nutrient absorption, growth rate and economic aspects of poultry". Interestingly, probiotics have many beneficial aspects and can enhance growth in human beings, animals, poultry, and fish [8 - 11]. Probiotics include several species such as bacteria, yeast, or fungi, and the most prevalent used probiotics are *Bifidobacterium, Bacillus subtilis, Streptococcus,*and *lactobacillus,* which are also capable of reducing many pathogenic bacteria like *Escherichia coli*, *Clostridium perfringens*, *Salmonella typhimurium, Staphylococcus aureus, etc* [12]. This article highlights the types and sources of probiotics, mechanisms of action, and their beneficial effects on health, immunity, and production in poultry.

PROBIOTICS TYPES AND SOURCES

The types of probiotics include bacteria, most often [*Lactobacillus, Bacillus, Bifidobacterium, and Enterococcus*] [13 - 16], yeast [*Saccharomyces cerevisiae* and S*accharomyces boulardii*] [17, 18] and fungi such as *Aspergillus* and

Candida species [19]. Most bacteria belong to *Lactobacillus* or *Bifidobacterium* species and present as normal inhabitants of the GIT [Autochthonous probiotics]. In contrast, other species that can be isolated from outside the host like fermented products and soil are can be defined as Allochthonous probiotics [20]. Interestingly, *Lactobacillus plantarum* and *Leuconostoc mesenteroides* can be isolated from non-conventional sources such as fresh fruits and vegetables and can be used as probiotics [21].

Whatever the probiotic source, they must be safe and can't induce any adverse effects on the host or contribute to infectious diseases. Moreover, they should be identified on the basis of genotype and phenotype and check their bile and gastric juice tolerance. In addition, a probiotic used as a feed supplement in animals or poultry may contain a single strain or a mixture of two or more species [22]. These products are produced by fermentation with strain-specific pH and temperature and dried by spray or freeze-drying process [23].

There are various forms of commercial probiotics such as liquid, gel, powder, paste, and granules available in capsules, sachets, tablets, *etc*. Interestingly, dry probiotic form has higher survival life during storage and better resistance to gastric juices. Moreover, hydroxypropyl methylcellulose phthalate 55, when used as a matrix for tablet probiotic form, increased its viability in poultry [12, 24]. A probiotic must be provided in adequate amounts in the feed for animals or poultry that recommended 10^9 cfu/kg of feed for most probiotic products [25]. However, Mountzouris *et al.* [15], added a commercial multi-strain probiotic [PoultryStar ME] in poultry feed at 10^8 cfu/kg. They observed that the growth rate of broiler chickens was enhanced without an observable modification of caecal microflora composition while increasing the dose to 10^9 cfu/kg, the caecal coliform populations were reduced. Not all microorganisms can be probiotic as probiotic strains must be isolated from healthy individuals and appropriately selected with specific criteria to be able to give the desired effect and meet all required conditions to be commercially applied according to the recommendations of the European Food Safety Authority [26] and Food and Agriculture Organization [23] as in Fig. (**1**).

"Direct-fed Microbial [DFM] products" has been used by Food and Drug Administration [FDA] to define probiotics that are used in animal feed that means "products that are purported to contain live [viable] microorganisms [bacteria and/or yeast]" [27]. The Association of American Feed Control Officials [AAFCO] publications listed the microorganisms that can be used as DFM products and have been approved by FDA (Table **1**).

CHAPTER 11

Phytogenic Substances: A Promising Approach Towards Sustainable Aquaculture Industry

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Abstract: The aquaculture industry has shown rapid growth over the last three decades, especially with improving the farming systems. However, the rapid expansion and intensification practices in the aquaculture sector have been marred by increased stress levels and disease outbreaks, and subsequently, high fish mortality. Excessive use of veterinary drugs and antibiotics in aquaculture poses a great threat to human and aquatic animals' health, as well as to the biosystem. Furthermore, exposure to various pollutants such as industrial effluents and agricultural pesticides may cause devastating toxicological aspects of fish and adversely affect their health and growth. Besides, with a growing world population, there is a growing interest in intensifying aquaculture production to meet the global demand for nutritional security needs. Uncontrolled intensification of aquaculture production makes aquatic animals both vulnerable to, and potential sources of a wide range of hazards include pathogen transmission, disease outbreak, immunosuppression, impaired growth performance, malnutrition, foodborne illness, and high mortality. Plant-derived compounds are generally recognized as safe for fish, humans, and the environment and possess great potential as functional ingredients to be applied in aquaculture for several purposes. Phytogenic additives comprise a wide variety of medicinal plants and their bioactive compounds with multiple biological functions. The use of phytogenic compounds can open a promising approach towards enhancing the health status of aquatic animals. However, further *in-vivo* trials are necessary under favorable conditions with controlled amounts of identi-

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fied bioactive compounds along with toxicity testing for fish safety towards a realistic evaluation of the tested substance efficacy.

Keywords: Antibiotic alternative, Antimicrobial activity, Antioxidant activity, Aquaculture, Gut microbiota, Immunostimulants, Phytogenic.

INTRODUCTION

Fish supply worldwide mainly depends on aquaculture, which presents about two-thirds of the total fish market. The growth of this sector has been predicted to increase by more than 60% between 2010 and 2030 [1]. However, the demand for animal proteins, particularly from fish sources, is forecast to increase with world population growth. Consequently, intensification of aquaculture operations has become necessary to meet the market demands of fish products. However, the application of this practice may entail some challenges, such as crowding, stress, and the rapid spread of diseases, which make aquatic animals more vulnerable to different stressors, resulting in immunosuppression and high mortality, and consequently significant economic losses.

To avoid economic losses caused by different factors in aquaculture, producers tend to use several veterinary medicinal products to control various diseases and improve the health status of fish. The regular administration of these chemical products to the ponds through feed additives or other routes may affect the ecosystem and fish and human health *via* their undegradable residual fractions in the biological system. In these circumstances, there was an urgent need to improve the health status of fish by stimulating growth, the immune system, and resistance to various diseases and environmental stressors with natural and inexpensive alternatives. For decreasing the global concern about this health and environmental safety risk, the use of phytochemicals in aquaculture presents an environmental-friendly substitute. It contributes to more sustainable aquaculture production systems due to the diversity of biological functions of these compounds and their ability to biodegradation in the ecosystem. Plant-derived compounds are generally recognized as safe for fish, humans, and the environment and possess great potential as functional ingredients to be applied in aquaculture for several purposes [2].

Due to the presence of various molecules in plant products with different chemical structures and the possibility of synergetic effect among these molecules, plant extracts and other phytochemicals can effectively improve fish health with various mechanisms at the same time [3]. The use of phytogenic feed additives contribute to modulating gut microbiota [4], improving gut functions [5], boosting the immune system [6], triggering disease resistance [7 - 9] and alleviating the inflammation and oxidative stress [10, 11], leading to enhancement of growth performance [7, 12, 13]. Furthermore, the use of plant-derived compounds can be used for the treatment and prevention of parasitic and fungal diseases in aquatic animals *via* their application in therapeutic baths [14, 15].

With banning antibiotic growth promoters' usage and growing concerns about superbugs, the search for novel alternatives to reduce antibiotic use in the aqua feed will significantly increase in the coming years. In this chapter, we reviewed scientific evidence that phytogenic compounds promote growth performance, boost immunity functions, mitigate oxidative stress and inflammation, maintain gut health, enhance beneficial intestinal bacteria, and reduce the adverse effects of pathogens in aquaculture (Table **1**).

Table 1. Potential of phytogenic feed additives in aquaculture.

Fish Species	Phytogenic Additives		Form/Part Utilized	Dietary Supplementation and Dose	Duration	Growth-promoting Activity	Immunomodulatory Activity	Antioxidant Activity	Antimicrobial Activity	Challenge with Pathogen	Ref.
	Scientific name	Common/ Commercial name									
Rainbow trout [*Oncorhynchus mykiss*]	*Origanum onites.*	Cretan oregano	Essential oil	0.125, 1.5, 2.5 and 3.0 mL/kg	90 days	FCR in fish-fed diets containing 1.5 and 3.0 mL/kg essential oil of *O. onites* was lower than other treatments.	Plasma lysozyme activity was significantly higher in fish-fed diet containing 3.0 mL/kg essential oil of *O. onites.*	Treatment diets did not improve the activity of antioxidant enzymes	Treatment diets improved disease resistance and survival rate.	*L. garvieae*	[21]
	Curcma longa	Curcumin	A yellow pigment derived from the plant *Curcuma longa*	1, 2 and 3%	56 days	The maximal weight gain and specific growth rate occurred at fish fed the diet containing 2% curcumin and feed conversion rate was improved in all treatments than control.	Treatment diets enhanced all the chosen immune parameters.	The highest values for antioxidant parameters were found in the group fed 2% curcumin.	Dietary supplements improved disease resistance and the relative percentage of survivals.	*A. salmonicida* sub sp. *Achromogenes*	[22]
	Zataria multiflora	A thyme-like plant	Hydroalcoholic extract	1, 2 and 3 g/ kg	56 days	Treatment diets did not affect growth; however, the survival rate was significantly improved in fish fed on 2 and 3 g *Z. multiflora*	Humoral immune responses and immune-related gene expressions were significantly increased in fish fed on 2 and 3 g Z. multiflora compared to the control group. Treatment 2g exhibited significantly high mucosal bactericidal activity and mucosal lysozyme activity.	Fish fed diet supplemented with 2g Z. *multiflora* had significantly higher plasma SOD and CAT and lower MDA levels compared to other groups	-	-	[23]
Channel catfish [*Ictalurus punctatus*]	-	Digestarom® P.E.P. MGE.	Essential oils that include carvacrol, thymol, anethol, and limonene.	200 g/ton	42 days	Dietary treatments did not affect weight gain and feed conversion ratio.	In the EO fish, mannose-binding lectin [MBL] levels were similar to non-challenged fish but significantly higher than non-treated fed fish.	The results demonstrate that essential oils improved antioxidant status.	The essential oils improved the survival of channel catfish challenged with *E. ictaluri.*	*Edwardsiellaictaluri*	[24]
African sharptooth catfish [*Clariasgariepinus*]	*Asimina triloba* and *Allium cepa* L.	Pawpaw–onion powder [POP] mixture	Pawpaw seed and onion peel powder	2.5, 5 and 10 g/kg.	60 days	The supplementation exerted no effect on the growth.	A significantly higher lymphocyte count was observed in treatment 10g/kg, whereas the 5.0g/ kg group recorded the highest hepatosomatic value.	Diet supplements have direct effects on the antioxidant response of *Clariasgariepinus* .	-	-	[25]

CHAPTER 12

The Beneficial Impacts of Essential Oils Application against Parasitic Infestation in Fish Farm

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Abstract: Aquaculture is a growing sector due to the high rising demand for fish, shrimp, oysters, and other products, which is partially conflicted by various infectious diseases. The infectious diseases affecting the production and inducing high mortalities cause substantial economic losses in this sector. Also, parasitic infections may induce severe mortality and morbidity in fish farms. Therefore, most farmers apply several kinds of antibiotics to control the problems induced by bacterial diseases and, to some extent, parasitic infections. The extensive usage of antibiotics to control or prevent pathogens may lead to the development of pathogenic resistant strains that might cause hazards to human health. Besides, there is a global trend toward reducing the application of antibiotics in aquaculture farms. Thus, there is a great effort to discover new natural and safe products with pharmaceutical properties, such as natural essential oils (EO). Essential oils are secondary metabolites of many plants (roots, flowers, seeds, leaves, fruits and peels) and their molecular structures provide a high antimicrobial and antiparasitic efficiency against pathogens. Consequently, it is essential to provide sufficient knowledge about the mode of action of EO against fish parasites and its future applications and directions in aquaculture.

Keywords: Antibiotics, Antiparasitic, Diseases, Essential oils, Parasites.

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INTRODUCTION

Worldwide, aquaculture is a fast-rising practice due to high demands for aquaculture-derived foods and other products for human uses. It is a vital source of nutrition, food, livelihood and economic income for millions of people worldwide [1]. In 2018, the world aquaculture production was around 114.5 million tons from aquatic animals, with a total farm gate sale value of US$ 263.6 billion [2].

Several factors affect fish culture production, such as inadequate diet, high stocking density, low oxygen water content, pollution, and infectious diseases, including parasitosis. The intensive production from fish farms leads to a high incidence of parasitic diseases that threaten the sustainability of fish farming [3]. Many parasite infections may be responsible for huge economic losses; thereby, the application of sufficient controlling procedures and treatments is a vital challenge for fish producers [4]. Given the secondary adverse effects of synthetic treatments on antimicrobial resistance and residue in foods, phytotherapy has become a leading alternative strategy in controlling parasitic infections. Herbs may include one or more bioactive constituents with the potency for therapeutic effects [5].

Essential oils (EO) are naturally aromatic and volatile liquids extracted from various parts of medicinal herbs [6]. Several recent studies have proven the efficiency of some EO against bacterial [7], fungal and protozoal diseases [8, 9]. Even though there are more than 3000 EOs identified, less than 0.4% of them have been verified on fish parasites [1]. So, there is a need to conduct more experiments on the therapeutic potential of these products to determine the antiparasitic effects of other EOs for preventing fish parasites to maximize their benefits to hosts.

This chapter focuses on recent knowledge about *in-vivo* studies on the EOs against fish parasites. Also, we have highlighted the antiparasitic mode of action of EOs, along with their immunomodulatory role and potential use against both fish ectoparasites and endoparasites. There is an urgent need to explore EOs and their effective, safe dose levels to control endoparasite infections in fish. Therefore, the development of new products may be attained by considering the beneficial features of EOs. Moreover, EOs could be used as a practical alternative strategy for therapeutic compounds against several infections.

ESSENTIAL OIL RESOURCES, STRUCTURE AND BIOACTIVE MOLECULES

EOs are volatile compounds often present as a complex mixture of several constituents that are extracted from herbs [1]. The EOs are classified according to their chemical structures, mainly terpenes (hydrocarbons) like terpinene, myrcene, limonene, pinene, *p*-cymene, *a*- and *b*-phellandrene; and terpenoids like geraniol, linalool, menthol, 4-carvomenthenol, terpineol, carveol, borneol, citral, citronellal, perillaldehyde, carvacrol, thymol, safrole, eugenol, verbenol, menthone, pulegone, carvone, thujone, verbenone, fenchone, citronellic acid, cinnamic acid and linalyl acetate. Also, some EOs may contain the structure of oxides [1,8-cineole), methyl anthranilate, coumarins and sesquiterpenes such as zingiberene, curcumin, farnesol, sesquiphellandrene, turmerone, and nerolidol [10, 11]. Many of these secondary constituents extracted from herbs showed varied antiparasitic activity [5, 12].

Many herbal plants such as *Thymus hyemalis, Thymus glandulosus, Thymus zygis, Thymus vulgaris, Origanum dictamnus, Monarda fistulosa, Origanum vulgare, Origanum onites* and *Origanum compactum* contain a natural monoterpene compound called thymol and 2-isopropyl-5-methylphenol [13]. The ginger EO is extracted from ginger (*Zingiber officinale* Rosc, Zingiberaceae). The main bioactive molecule is citral, which has high antibacterial activities and could be used as a dietary supplement to treat pathogens [15]. In addition, *Hedeoma patens*, *Lippia graveolens*, *Lippia palmeri*, *Lippia alba*, *Origanum dictamnus*, *Origanum hirtum*, *Origanumonites*, and *Origanum vulgare* are common oregano plant species belonging to the Verbenaceae family, which are used for extraction of *Origanum* EO [16]. Table **1** illustrates many studies showing the effectiveness of various EO in reducing parasitic infection in several fish species.

Table 1. ***In-vivo*** **and in** ***in vitro*** **influence of different essential oils and their derivative molecules for different fish species infected with parasites.**

References	Solvent	Frequently	Dose	Fish Species	Essential Oil	Parasite
Firmino, Vallejos-Vidal [86]	water	104 days	0.5%	*Sparusaurata*	microencapsulated blend of garlic, carvacrol and thymol essential oils	*Sparicotylechrysophrii*
Pereira, Oliveira [102]	ethyl alcohol (70%).	24 hours	LC_{50}. 67.97 µg/L and 59.55 µg/L.	In *in vitro*	*Cymbopogon citratus* (Poaceae)	*Argulussp and Dolops discoidalis*
Barriga, Gonzales [103]	ethyl alcohol (70%).	After 9 hours	700 mg/L	*Colossoma. macropomum* fingerlings (30 ± 5 g) and a large Serrasalmidae	*Lippia grata* (Verbenaceae)	monogeneans

CHAPTER 13

The Role of Antimicrobial Peptides (AMPs) in Aquaculture Farming

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Abstract: Antimicrobial peptides (AMPs) are the vital constituents that stimulate the innate immune defense system against pathogens and perform several biological activities, which provide the first defensive line against infectious diseases. Owing to their unique structure, they can be utilized as a therapeutic strategy for infectious diseases in fishes. Several kinds of AMPs are reported in fishes with broad-spectrum antimicrobial properties. Besides, the bacterial cells cannot develop resistance strains against these cationic compounds with low molecular weight. Thus, AMPs may be considered an alternative to antibiotics to prevent or control infectious diseases in aquaculture. It is essential to provide sufficient knowledge about the mode of action of AMPs against fish pathogenic agents and their future applications.

Keywords: AMPs, Antibiotics, Antifungal, Antimicrobial, Antiparasitic, Antiviral.

INTRODUCTION

Antimicrobial peptides (AMPs) are small endogenous peptides (less than 13 kDa), having both hydrophilic and hydrophobic parts and a cationic charge. These low molecules are vital constituents, promoting the immune system against a wide range of pathogenic microbial agents [1]. The AMPs could be isolated from various organisms such as insects, plants, animals and humans, and they are identified to protect living organisms against pathogens [2]. The AMPs display

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massive variations in structures and sequences but reveal some common properties such as cationic charge, amphipathic and hydrophobic structure [3, 4].

The AMPs have a positive charge constructed from nearly 20 to 50 amino acid sequences and have some essential amino acids, such as arginine and lysine [2]. The presence of disulfide bridges in AMPs structure is responsible for the positive charge and hydrophilic features [2].

Several types of AMPs, such as defensins and cathelicidins, have been identified and isolated from several mammals [6]. The variation in the structure of cationic AMPs delivers high antimicrobial activity to these residuals [5]. Besides the antimicrobial activity of AMPs, these cationic compounds have numerous biological effects like an immunomodulatory role against the virus, parasitic and fungus infections [7, 8].

Recent studies have identified several resources of AMPs and their importance as antibacterial, antiviral, antiparasitic and antifungal diseases. In this chapter, the common AMPs used against fish culture diseases have been discussed in detail, along with the mode of action of AMPs. Usage, advantage and disadvantage of these AMPs have also been illustrated.

Antimicrobial Peptides (AMPs) Types and Structure

The first AMP, cecropin, was isolated from diapausing pupae of the lepidopteran Hyalopholacecropia by Boman and Hultmark [9]. Since this discovery, multiple AMPs have been characterized and identified in many vertebrate and invertebrate species (Hertru *et al*., 1994). The structural and functional characteristics of AMPs depend upon their amino acid sequences [10].

The AMPs could be categorized into three main classes: firstly, α-helical, with open and closed rings including disulfide-combined β-sheets, and prolonged features with a prevalence of a single amino acid (for instance, tryptophan, proline, or histidine) [11] (Fig. **1**). The α-helical AMPs include cecropins, magainins, pleurocidins, chrysophins, piscidins, moronecidins, misgurnin, pardaxin and cathelicidins have been isolated from insects, amphibian or teleost fish [12-18] Chang *et al*. 2006). The α-helical AMPs are rarely found in invertebrates, although styelins, dicynthaurin, halocidin, clavanins and clavaspirin were detected in tunicate hemocytes [19 - 22].

The second class of AMPs is β-sheet, which includes amino acids combined with disulfide peptides such as defensins (recently isolated from rainbow trout), mytilins, myticins, mitomycin, tachyplesins, polyphemusins, and hepcidins [23 - 30]. The third class of AMPs is defined as proline-rich compounds with an extended single amino acid structure. Astacidin, an AMP enriched with proline synthesized from hemocytes of crayfish *Pacifastacus leniusculus*, has its molecular weight similar to bovine bactenicin generated from shore crab, *Carcinus maenas* (6.5 kDa) [31, 32]. Also, callinectin isolated from blue crab, *Callinectes sapidus*, contains extensive quantities of arginine and proline with a 3.7 kDa molecular weight, but their sequences are typically proline-rich AMPs [33]. Moreover, penaeidins AMPs isolated from the small spider crab, *H. Araneus*, and shrimp, *Penaeus vannamei*, consisting of 37 amino acids dominate with proline and arginine followed by cysteines [34, 35].

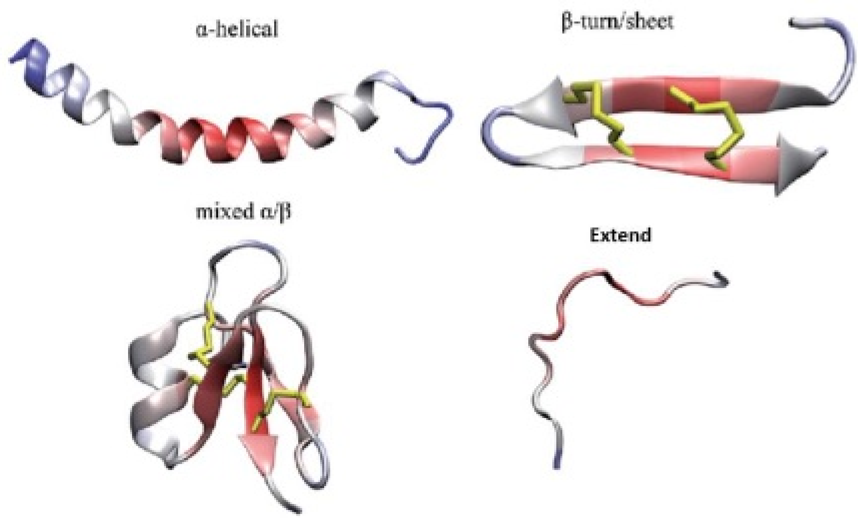

Fig. (1). The main classes of AMPs.

Resources of Antimicrobial Peptides

Naturally, AMPs have been discovered in all prokaryotic and eukaryotic creatures with a broad spectrum of antimicrobial effects [36]. The nisin was the first AMP isolated from the *Lactococcus lactis*, containing a 34-amino acid peptide belonging to the bacteriocins family [37]. Also, the melittin peptide was isolated from the Iranian honey bee (*Apis melliferameda*) venom by high-performance liquid chromatography, which has a 26-amino acid peptide [38] and showed anticancer properties besides its high antimicrobial effects. In 1939, the gramicidin was isolated from *Bacillus brevis* and identified as a leading AMP, which exhibited high effectiveness against various pathogenic bacteria and was commercially manufactured as safe antibiotics [38, 39]. Recently, AMPs have been isolated from different resources such as plants, mammals, marine invertebrates, insects, and other organisms. For instance, the purothionin compound was isolated from the wheat endosperm and categorized as AMP [40].

SUBJECT INDEX

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Mohamed E. Abd El-Hack

Dr. Mohamed E. Abd El-Hack, is an Assistant Professor of Poultry Nutrition, obtained his Bachelor's degree in 2007 and the Master's Degree in 2011 and the PhD Degree in 2015. Dr. Abd El-Hack was awarded the State Encouragement Prize in Agricultural Sciences in 2018. He also received the Medal of Excellence of the First Class from the President of the Arab Republic of Egypt in 2020, in addition to receiving some international awards. According to the Stanford University classification, his name was included in the list of Top 2% of influential scientists in biological sciences. Dr. Abd El-Hacks research focuses on using natural alternatives to antibiotics in feed to produce safe and healthy food from poultry meat and eggs. The research is also concerned with using alternative feed materials from various agricultural wastes. This trend has positive impacts on the environment and the economics of poultry production in Egypt.

Mahmoud Alagawany

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