***Review Article***

**Emerging Trends in the Use of Nutraceuticals for Improved Poultry Production**

**ABSTRACT**

The human body needs a diverse range of food and nutrients for optimal functioning, linking nutrition to health and reducing disease risks. This connection has led to the development of the concept of nutraceuticals. The word “nutraceutical” was coined in 1989 by Dr. Stephen DeFelice, who defined it as a food or food component capable of preventing or treating disease. In 2022, the global nutraceutical market was valued at USD 291.33 billion and is projected to grow at a CAGR of 9.4% from 2023 to 2030 driven by rising consumer demand for dietary supplements that enhance immunity and prevent various disease outbreaks.Nutraceuticals have gained recognition for their potential to prevent diseases and act as alternatives to antibiotics. The use of antibiotics and growth promoters in poultry nutrition can lead to antibiotic resistance and residue contamination in poultry products, which may affect human health. Nutraceuticals help mitigate these risks by supporting gut health and offering protective effects without disrupting beneficial microbiota, unlike antibiotics, which indiscriminately affect both harmful and helpful bacteria. Nutraceuticals have attracted growing interest in poultry nutrition due to their health benefits, improved feed conversion efficiency, enhanced productivity through immunomodulatory properties, and the absence of side effects or microbial resistance. They can be added to poultry feed in the form of minerals, amino acids, and vitamins, either individually or in combination. In this frame, this review aimed to sum up the trends in the use of nutraceuticals with a special focus on their influence on poultry production sector.

**Keywords:** Broilers, Phytobiotics, Functional food, Probiotics, Antioxidants , Spirulina, Curcumin

**1. INTRODUCTION**

Chicken meat has become one of the most affordable sources of high-quality lean protein. In 2023/2024, global production reached 103.83 million metric tonnes, as reported by the USDA Foreign Agricultural Service’s “Livestock and Poultry: World Markets and Trade.” In 2020, poultry accounted for nearly 40% of global meat production. The United States is the leading producer, responsible for 20% of global output, followed by Brazil and China, each with 14%. According to the United Nations Food and Agriculture Organization, pork is the most consumed meat worldwide, making up 36% of global consumption, followed by poultry at 33%, beef at 24%, and goats/sheep at 5%. Antibiotic growth promoters (AGP) have been used in broilers to increase live weight and feed efficiency (Diaz et al. 2019). However, its use in poultry feed has been restricted in Europe and the United States because it may promote the growth of antibiotic-resistant bacterial strains, resulting in antimicrobial resistance. The safety of animal-derived foods has been called into question in recent years due to outbreaks of zoonotic diseases and food-borne bacterial infections, increased veterinary drug residues in poultry products, and antibiotic-resistant microbial growth. These instances have forced health professionals and Veterinarians to actively monitor any food quality and safety issues that may occur in animal-derived foods. Because animal production is not the only aspect of animal nutrition, it is important to consider health and disease concerns related to poultry feeding practices, environmental management, metabolic and physiological stress factors, and the selective use of feed additives and supplements on yield and product quality by improving bird immune and gut health. When it comes to antibiotic growth promoters, the narrative began in 1940 when a study by (Moore et al. 1946) found that feeding antibiotics had a growth-promoting impact. The search for an alternative to animal protein growth factor B12 sparked interest in antibiotics, which were found to be partially responsible for growth promotion in the absence of animal protein.

Several antibiotics were first used to boost growth, but by the late 1960s, the Swan Committee had reviewed their use due to the possibility of antibiotic resistance developing. They discovered that administering antibiotics to farm animals has specific dangers to the health of both humans and animals. It had caused resistance in gut bacteria of animal origin. This resistance was transferable to other microbes. Sweden was the first country in Europe to entirely prohibit the use of antibiotic growth promoters in 1985.Therefore, it has been demonstrated that the indiscriminate use of antibiotics in animal husbandry increases the threat of antimicrobial resistance in the population, leaves residues in animal products, and pollutes the environment. Now, society is more concerned with consumer confidence, food security, and information technology. Gut ecosystem modulation by pro-nutrient feed additives, perinatal nutrition, epigenetic programming, feed manufacturing technology, feed science, and computational knowledge to optimize nutrition and feeding programs will be the main factors influencing poultry nutrition over the next 25 years. The introduction of nutraceuticals as a potential method of delivering animal food with higher safety margins is implied by the fact that animal nutritionists are closely monitoring the replacement of feed ingredients and the enhancement of their nutritional value by supplemental enzymes, as well as the modulation of the gut ecosystem by pro-nutrient feed additives.

Using a feed supplement has different benefits depending on the farm’s circumstances, such as the presence or absence of heat stress, a high microbial load, inadequate ventilation, and nutritional stress, to mention a few. Stressful environmental factors set off a series of events in the broiler’s physiological response including release of pro-inflammatory chemicals leading to inflammation as part of a natural stress response, which has an impact on feed intake and growth (Karl et al. 2018). It may be possible to increase the broiler chicken’s resistance to stress by adding supplements to their feed, which contain active metabolites and natural antioxidants. For this reason, the researchers are searching for additives at significantly lower costs.

Feed additives are substances, microorganisms, or preparations (other than pre-mixtures and feed materials) that are purposefully added to feed or water to carry out one or more of the following functions: they can improve the health, physical properties of the feed to make it more suitable for processing and storage and nutritional value of the feed for better feed utilization in order to promote the poultry growth. By using feed additives and supplements in animal feeding, such as for broilers, one can increase daily growth rates, improve the quality of animal products, enhance feed conversion efficiency, lessen the negative environmental effects of animal waste and increase disease resistance. Nutraceuticals are found to obtain poultry products (e.g., eggs, meat) enriched with biologically active compounds like PUFA (polyunsaturated fatty acids), antioxidants, antimicrobials, vitamins, and organ- protective elements (Alagawany et al. 2019).

**2. EMERGING NUTRACEUTICALS**

Development of the modern intensive poultry farming has increased the importance of feed additives and supplements in chicken feed. The term “Nutraceutical” is a combination of two words, i.e., “Nutrition” and “Pharmaceutical.” Nutraceuticals are readily available food additives produced from natural ingredients used in both human and animal nutrition and have evolved from sources of nutrition to a vital component of support therapy for preventing and treating a wide range of diseases. They also serve an important role in improving overall health, increasing life expectancy, maintaining the structure and function of the body, and slowing the aging process. Given the risks connected with chemical medicines, such as antibiotic resistance and drug residues in food, some countries have restricted the use of antibiotics in poultry diet. As a result, there is a high demand for organic compounds that encourage comparable growth and are favourable to poultry health. Nutraceuticals have shown to serve as antioxidants, immunity boosters, gut microbiota modulators, growth rate enhancers among having other potential roles in improving production performances and yielding high quality poultry products. This growing trend highlights the rising significance of nutraceuticals in modern poultry nutrition.

**Emerging nutraceuticals for improved poultry production can be divided into:**

1) Dietary supplements —Probiotics, Prebiotics, Antioxidants, Enzymes (Fig.1)

2) Nutritional Substances—Amino acids, Vitamins, Minerals, Fatty acids

3) Herbs, Spices, Fruits, Vegetables and fibres

4) Phytochemicals, Bioactive peptides and Functional foods

**2.1. Phytobiotics and Phytosterol**

Phytobiotics, phytochemicals, or phytogenics are natural compounds obtained from plants. The Addition of phytobiotics has shown beneficial results in poultry nutrition in terms of increased feed intake, growth rate, palatability, immune stimulation, meat quality, digestibility, and improved microflora of the gut. They can be easily found in fruits, vegetables, spices, essential oils, grains, and legumes at low cost (Dhama et al. 2015). They have antibacterial, antioxidant and growth-promoting qualities. Betaine is a phytobiotic that can be obtained from beets, spinach, wheat, oat brans, barley, etc., and has proven to boost poultry output by assisting in the management of heat stress, improving growth performance, nutrient digestibility, muscle yield, fat metabolism, and immunity (Salamat and Ghasemi 2016). As methyl donors, betaine and folic acid can make up for the absence of labile methyl groups in poultry birds’ diets that comprise soybean and maize (Pillai et al. 2006). The proper growth and development of broilers with protein synthesis and feather growth requires methionine supplementation, which is the first limiting amino acid in poultry. It also reduces oxidation stress by increasing glutathione. Betaine contains approximately 3.75 times as many methyl groups per molecular weight as methionine does. Betaine in animal feed reduces feed expenses by substituting choline chloride and methionine (Nutautaitė et al. 2020) and can be used to protect intestinal function against osmotic stress in cases of diarrhea or coccidiosis in animals (Saunderson and MacKinlay 1990).

Phytochemicals such as soy proteins and soy isoflavones are beneficial medicinal nutrients possessing anticancer, anti-hyperglycemic, anti-hyperlipidemic, anti-hypertensive, antioxidant, neuroprotective, and anti-inflammatory properties. Phytobiotics also involve essential oils (thymol, cinnamaldehyde, terpenes, carvacrol, piperine, xanthophylls) and phenolic compounds such as flavonoids (Dhama et al. 2015). Studies with cinnamon had a wide array of beneficial effects in poultry, including antioxidant capacity to reduce and protect against oxidative stress, increased feed intake, improved digestibility of nutrients, improved growth performance (O’Bryan et al. 2015), maintenance of gut microflora, and strong antibacterial, anti-inflammatory, antimicrobial, analgesic, antidiabetic, anticancerous, immunomodulatory activity (Saeed et al. 2019). Cinnamon’s phenolic components also increase villus height and surface area, as well as the effectiveness of food absorption and digestion in the intestine (Ali et al. 2021).

Phytosterols are naturally found in vegetable oils, nuts, seeds, grains, wooden pulp, etc. Consuming phytosterols lowers blood LDL levels, increases hepatic uptake of LDL, and decreases cholesterol absorption, all of which help to prevent cardiovascular illnesses. Plant sterols are formed from grains like soy, corn, and sunflower and have proved to improve the development of muscle in chicken embryos and growth of chicks (Poli and Visioli 2019).

**2.2. Spices and Herbs**

Chicken industry has made substantial use of many Ayurvedic herbal remedies. It is asserted that meals containing spices and herbs may reduce the likelihood of many disorders and are particularly beneficial for enhancing quality of life. Researchers have discovered that herb-based medications like Livol and Zeestress have immune-potent effect, hepatoprotective properties (Parida et al. 1995). Herb and plant oils are commonly used in poultry feed to maintain health and boost productivity because they contain active ingredients that have beneficial effects on physiological processes and medicinal effects such as anti-inflammatory, antioxidant, and antibacterial properties (Reda et al. 2020). Cinnamon, garlic, oregano, rosemary, ginger, coriander, black cumin and turmeric are just a few of the herbs and spices that have been tested in poultry for their potential use as AGP alternatives.

Garlic (*Allium sativum*), has anti-hyperlipidemic and antihypertensive effects. It works by reducing endogenous cholesterol synthesis and eliminating cholesterol and its by products in the faeces. This contributes to the production of an advantageous HDL/LDL ratio (Chakraborty and Roy 2021). Thio-sulfinates are the most abundant class of organo-sulfur compounds, which can be linked to increased benefits associated with consumption of garlic (Lawson et al. 2001). Allicin makes up 70% of the total thio-sulfinates and is the primary bioactive component of garlic. The active compound in garlic has some beneficial effects for livestock, including hypocholesterolemic effects, growth-promoting properties, and antioxidant activities. (Lewis and Lewis 2003). Garlic is considered as plant with antibiotic, anticancer, antioxidant, immunomodulatory, anti-inflammatory & cardiovascular protecting properties. Cinnamon (*cinnamomum*) has been found to enhance the sensory attributes of the meat, suggesting that a 0.5% inclusion of cinnamon powder can be used as a phytobiotic alternative to antibiotic growth promoters in broiler production (Singh et al. 2014). Additionally, cinnamon supplementation has been found to decrease Eimeria oocyst shedding and serves as an effective therapeutic agent against coccidiosis in poultry (Youn et al. 2008).

Curcumin (diferuloylmethane), a polyphenol in turmeric, has anti-inflammatory, anticarcinogenic and antioxidant effects. Turmeric rhizomes, beet roots, spinach leaves, and cucumber fruits have been reported to possess anti-tumor properties. In a study conducted by (Hussein 2013), it was found that supplementation of 7 g/kg of diet (turmeric powder) to broiler chickens improved their body weight gain, liver, gizzard, and periventriculus performance index and relative growth rate (Kanani et al. 2016) concluded that dietary supplementation of cinnamon and turmeric, either alone (0.25%) or together (0.5%), improves the performance of broiler chickens under heat stress by decreasing lipid peroxidation.

Feeding of water fern, *Azolla pinnata*, to broilers at a 2.5% level showed a positive effect on breast muscle yield and gizzard weight and lowered the meat pH, which was found to be enhanced upon adding DFM (direct-fed microbial) to the azolla-based diet (Shambhvi et al. 2020). The plant compounds, along with their source and therapeutic use, have been mentioned in Table 1. The growth performance of feed additives according to the literature search has been mentioned in Table 2.

**2.3. Fruits, Vegetables and Dietary Fibres**

Dietary fibre is a natural component of plants that consists of non-starch polysaccharides (NSP), oligosaccharides, and lignin that escape digestion and enzymatic hydrolysis. Insoluble dietary fibre in broiler diets helps in the proper modulation of intestinal morphology, increase in growth performance, functioning of the digestive system, and its development, and efficient nutrient absorption (Sittiya et al. 2020). Fermentation of fibres in the gastrointestinal tract leads to the formation of SCFAs, such as butyric acid that acts as an energy source of intestinal epithelium, and antimicrobial and anti-inflammatory compounds (Namkung et al. 2011). Buckwheat, fava beans, and hemp flour enriched with anthocyanins may have applications in the prevention and treatment of chronic diseases, in addition to displaying the use of sustainable and environmentally friendly practices in feed units. Rice bran has zeaxanthin and lutein, which improve vision and prevent cataracts. Corn is a great supplier of folate and fibre. Broiler chicks were fed with basal feed supplemented with vegetable waste from potatoes, spinach, and cauliflower. The results concluded that the inclusion of vegetable waste at 25% in the diet of broiler birds led to an increase in body weight as well as had a positive effect on blood profile and carcass yield (Nisar et al. 2022). Better meat lipid oxidation status and better meat mineral content was observed when birds were fed vegetable waste (VW) at 25, 50, 75, and 100% of the diets, respectively, compared with 100% commercial feed, and results indicated that VW may replace up to 75% of commercial broiler feeds with beneficial effects (Raza et al. 2019). Tangerines, grapefruits, lemons, and oranges are among the citrus fruits that contain the weak organic acid known as citric acid (2-hydroxy-1,2,3-propane-tricarboxylic acid). The results of a 35-day study evaluating Citric Acid (CA) as a feed additive in poultry broiler feed with lower mineral content of calcium (Ca) and Total Phosphorus (TP) showed activation of homeostatic mechanisms of Ca and phosphorus digestion and absorption, improved FCR, improved carcass characteristics, and higher growth rate, as well as better nutrient utilization with a positive impact on dressing percentage (Katoch et al. 2023).

**2.4. Probiotics and Prebiotics**

Adding appropriate supplements to poultry birds’ diets, such as probiotics, growth boosters, and enzymes, can improve their digestive efficiency. Probiotics and prebiotics are recommended for use in poultry feed to regulate feed intake, boost weight gain, improve feed conversion ratio by reducing digestive disturbances, promote digestion, protect beneficial intestinal microbes against pathogenic bacteria through antagonism and competition, activate immunological response, increase cytokines release, reduce ammonia synthesis, improve nutrient absorption, reduce death rates and reduce the cost of poultry production. (Al-Khalaifah 2018).

Parker coined the term “probiotic” in 1974 and defined it as live microorganisms and substances that contribute to intestinal microbial balance and DFM (direct-fed microbial) were defined as live microbial feed supplements that improve microbial balance in the animal gastrointestinal tract and thus are beneficial. DFM is thought to have two beneficial effects: first, it helps to maintain a healthy microflora in the gastrointestinal tract by preventing the growth of harmful microorganisms; second, it improves intestinal health, which increases intestinal enzyme activity and nutrient availability, thereby increasing nutrient utilization. N, Ca, and P retention are improved in laying hens when Lactobacillus-based DFM is added to their diet (Nahashon et al. 1994). According to the United Nations and World Health Organization expert panel, a “Probiotic” is a live organism that benefits living beings when given in sufficient quantities. Commonly used microbial species as probiotics include Gram-positive bacteria *(Enterococcus*, *Lactobacillus, Pediococcus,* and *Bacillus).* Some other probiotics are microscopic fungi, such as strains of yeast (*Saccharomyces cerevisiae)*. A probiotic includes the following: it is neither pathogenic nor toxic to the host, is capable of exerting a beneficial effect on the host animal, i.e., increased growth and production, is capable of survival and metabolization in the gut environment, i.e., should be resistant to low pH and should fall in the category of GRAS (generally regarded as safe). Probiotics boost poultry birds’ immunity in two ways: (a) flora from probiotics gets penetrated through the gut wall, and there it starts multiplying to a limited extent, or (b) dead organisms produce antigens that get absorbed, thus stimulating the immune system (Havenaar and Spanhaak 1994). Apata in 2008 observed that broiler chicks fed diets supplemented with culture of *Lactobacillus bulgaricus* had an improved humoral immune response, and (Kannan et al.2005) discovered that dietary supplementation of *L. sporogenes* significantly improves immunity to Ranikhet (New Castle) disease in broilers. Another mechanism suggested is competitive exclusion, which prevents opportunistic pathogen colonization by probiotic bacteria. Ramesh et al. (2000) found that birds fed *L. acidophilus* had decreased surface pH in the duodenum, jejunum, ileum, and cecum which is harmful to undesirable microflora.

Lactate, succinate, short-chain volatile fatty acids (SCVFAs), acetate, propionate, butyrate, and bacterial biomass are among the metabolic end products that are better absorbed when probiotics or DFM are taken. The hens absorb and digest most of the VFA that gut bacteria create, which helps them meet their energy needs. By making them more soluble, these short-chain fatty acids help enhance the absorption of minerals. Therefore, probiotics improve bone mineral density and mineral content while simultaneously increasing mineral bioavailability (Mutuş et al. 2006). In a research study it was reported that by usage of probiotics, an increase in crypt cells proliferation of small intestines and an increase in the height of ileal villus was observed (Awad et al. 2009). In 2017, Katoch et al. isolated *Lactobacillus casei* from leopard faeces (*Panthera leo*) and administered it to Vancobb commercial poultry broiler birds up to 6 weeks of age, which improved the growth performance of the birds at 6.8 x 108 cfu/ml on an overall growth performance. The inoculation of poultry birds with *Lactobacillus rhamnosus* bacteria has a beneficial effect on their overall growth performance and increased protein content in their meat, while their crude fat and total cholesterol contents were decreased (Pietras et al. 2001).

Prebiotics are non-digestible, fibrous compounds that do not hydrolyze or get absorbed in the gastrointestinal tract but can be utilized as substrates for probiotics and the most used prebiotics are non-digestible fructooligosaccharides. Other examples of prebiotics used in the poultry sector are fruits, legumes, cereals, oligofructose, galacto-oligosaccharides, xylo-oligosaccharides, lactulose, isomalto-oligosaccharides and pyrodextrins.

**2.5. Antioxidants**

Reactive oxygen species (ROS) are free radicals derived from nitrogen and oxygen. Antioxidants are necessary to stop lipid oxidation, which lowers the quality and safety of feedstuffs. Numerous antioxidants are derived from nutrients such as carotenoids, ascorbic acid (vitamin C), tocopherols and tocotrienols (vitamin E), and low molecular weight substances like glutathione and lipoic acid. Free radical quenching processes are catalyzed by antioxidant enzymes such as glutathione reductase, superoxide dismutase, and glutathione peroxidase. On the other hand, oxidative reactions are catalyzed by metal-binding proteins such as ceruloplasmin, albumin, ferritin, and lactoferrin. There are other endogenous antioxidant agents, including ubiquinone (coenzyme Q10), bilirubin, NADPH, and NADH, uric acid, thiols (glutathione, N-acetyl cysteine, and lipoic acid), enzymes (copper/zinc and manganese-dependent superoxide, selenium-dependent glutathione peroxidase, and iron-dependent catalase), and dietary antioxidants (vitamin C, vitamin E, beta carotene) and oxycarotenoids (lutein and lycopene). Plant polyphenols (flavan-3-ol), flavonols, tannins, anthocyanins, and derivatives of phenolic acid proanthocyanidins (Pas), which are composed of procyanidin and esterified gallic acid, are among the physiologically active phenolic compounds found in grape seed extract. These compounds prevent lipid oxidation in poultry during gastric digestion (Bonilla and Sobral 2016).

**2.6. Amino acids**

Structural and functional units of protein are called amino acids, divided into two nutritional categories: non-essential (produced by the body) and essential (unable to be produced quickly enough to satisfy the body's metabolic needs). Protein’s structural and functional building blocks, amino acids are divided into two nutritional categories: non-essential (produced by the body) and essential (unable to be produced quickly enough to satisfy the body’s metabolic needs). Amino acids are essential for many bodily functions. The poultry birds’ nutritional requirements must be supplemented with ten essential amino acids: lysine, methionine, threonine, tryptophan, arginine, leucine, isoleucine, phenylalanine, histidine, and valine. Threonine is the third limiting amino acid among these necessary amino acids, with methionine and lysine being the first and second limiting amino acids for broilers, respectively. For juvenile birds, glycine is an essential amino acid. Tyrosine and Cysteine are semi-essential amino acids, as they can be synthesized from phenylalanine and methionine, respectively.

Nutritional supplements with amino acid chelated trace minerals reduced the levels of pro-inflammatory cytokine gene expression and circulatory and intestinal heat shock protein 70 (HSP70) while improving gut health by lessening the effects of heat stress, according to research on day-old Cobb-500 male broilers (Baxter et al. 2020). When amino acids are supplemented, total short-chain fatty acids and caecal butyric acid are produced, which aids in growth, development, feed conversion efficiency, and immunity (Hilliar et al. 2020). Protein synthesis, DNA methylation, ROS elimination, and the synthesis of glutathione (GSH), a tripeptide that lowers ROS and protects cells from oxidative stress are all processes that methionine is involved in. The addition of dietary methionine to the feed increased the growth performance of 42-day-old broiler chickens (Wen et al. 2017). Threonine’s importance for gut health is demonstrated by the fact that its presence in the lumen speeds up the synthesis of mucosal protein and mucin (Nichols and Bertolo 2008). Threonine is a precursor to several compounds, including glutathione, which are vital to the body’s antioxidant defense mechanism. The greatest post-hatch relative development occurs in the GIT, particularly in the small intestine of chicken. The ability of newly hatched chicks to use nutrients, absorb food, generate several immunoglobulins, and grow may therefore be negatively impacted by early feed shortage, which may lead to decreased intestinal enterocyte length and villus surface area. (Uni and Ferket 2003). Early nutrition programming has been utilized to maintain homeostasis and a high body temperature during the first post-embryonic days, as well as to regulate the early growth and development of the GIT during the perinatal period from the late-term embryo to a few days after hatching. Both in-ovo and post-hatch feeding techniques are used. For instance, growth performance is improved by supplementing with L-lysine, threonine, L-histidine, and L-arginine, which are amino acids. Additionally, in ovo injection of sulfur-containing amino acids (cysteine and methionine) into heat-stressed embryonated eggs has been shown to lower the lipid profile of newly hatched broiler chicks and improve antioxidant indices and gene expression (Yadav and Jha 2019).

**2.7. Functional food**

Functional foods are the fortified food with bioactive compounds that are designed or modified using technology or animal nutrition to offer potential health benefits, disease prevention, enhancing immunity beyond basic nutrition. Mushrooms are being investigated as a conceivable source of functional food ingredients, with some species displaying positive results in terms of prevention of diseases. Functional food such as microalgae has bioactive compounds such as carotenoids, phycocyanin, and polyunsaturated fatty acids that have anti-inflammatory, healthy aging and antioxidant properties (Zanella and Vianello 2023). Microalgae (*Arthrospira platensis, Chlorella vulgaris, Staurosira sp., Schizochytrium sp.*) has proven to improve poultry meat characteristics, PUFA-ω3, EPA, DHA, and antibiotic activity. Spirulina has the potential to be a useful component in the diet of broiler chickens. It has the ability to raise PUFA levels in thigh meat by 5 g/kg (Bonos et al. 2016).

**2.8. Fatty acids**

The essential polyunsaturated fatty acids (PUFAs) found in cell membranes include omega-3 fatty acids—docosahexaenoic acid (DHA), eicosapentaenoic acid (EPA), and α-linolenic acid (ALA), and omega-6 fatty acids—arachidonic acid and linolenic acid. Omega-6 can be found in rapeseed soybean, sunflower oils, while omega-3 can be found in fish oils, plants, and nuts. Animal fat and olive oil contain non-essential fatty acids (omega-9). Eggs are not naturally rich in ω-3 PUFA; therefore, ω-3 PUFA supplementation in poultry rations is essential for obtaining enriched ω-3 PUFA eggs. Fatty acids play an important role in cardiovascular diseases. Rice bran contains omega-9 and folic acid, which lowers the levels of LDL cholesterol in the blood while increasing HDL. Chances of cardiac arrhythmias are reduced with the consumption of omega-3 fatty acids. PUFAs play a vital role in the poultry industry by boosting antioxidative qualities, positively influencing mineral metabolism, especially calcium, zinc, and magnesium; promoting bone development; boosting immunity; and enhancing the quality of meat and eggs (Oken et al. 2004). SCFAs (acetate, propionate, and butyrate) have a beneficial anti-inflammatory effect by preventing intestinal damage, and these SCFAs are formed by commensal bacteria. Foods rich in n-3 PUFA help broiler chickens' immune systems function better (Ibrahim et al. 2018).

**2.9. Bioactive Peptides**

Bioactive peptides have been separated from a wide variety of dietary proteins from plants and animals’ eggs and milk (casein and whey). The most common sources of animal protein are meat proteins. Soy, oats, pulses (chickpeas, beans, peas, and lentils), wheat, canola, flaxseed, and hemp seed are common plant sources for bioactive peptides. Casein and whey protein derived from milk contain natural angiotensin-converting enzyme inhibitors, and they also exert antihypertensive effects. Supplementation with carotenoids, bioactive peptides, botanical extracts, bioactive polysaccharides, etc., in various human trials has evidenced protection against UV radiation and fewer signs of aging (Pérez-Sánchez et al. 2018). Bioactive peptides obtained from fish waste have shown antioxidant potential, delay in lipid oxidation of breast meat of broilers and increased shelf life of meat in a study conducted by (Aslam et al. 2020). Sesame meal bioactive peptide was found to reduce *E. coli* in the gut, improve productive performance, gut microbial population, and intestinal morphology in broiler chickens.

**3. CONCLUSION**

Poultry production is one of the fastest growing agricultural sectors. Chicken meat has culminated into one of the cheapest sources of good quality protein and is the second most widely consumed meat in the world. Demand for chicken has been rising quickly globally in recent decades. Getting more affordable and higher-quality poultry production for customers is becoming increasingly vital. Genetic, environmental, and dietary factors are the key determinants of the quality of poultry meat. Robust growth of poultry birds is due to genetic selection. Owing to identified health concerns because of residual effects of antibiotics in the animal food chain, there is an increasing awareness amongst the consumers for a more natural and safer animal-based food. Thus, nutritionists are increasingly looking for nutraceuticals for use in poultry feed. More emphasis is on selective use of nutraceuticals to alleviate the stress on the bird by enhancing immunology and gut health without affecting the quality of product and yield.

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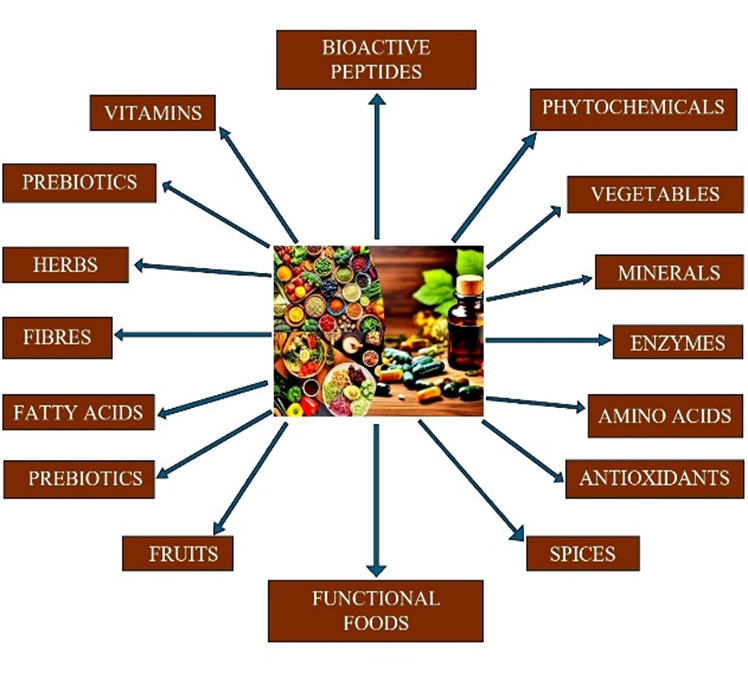
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**Table 1: Plant compounds along with their source and therapeutic use (Giannenas et al. 2020; Inoue, Hayashi, and Craker 2019)**

|  |  |  |
| --- | --- | --- |
| **Plant/ compound** | **Source** | **Therapeutic Use** |
| Oregano | *Origanum vulgare* | Anti-inflammatory, antioxidant, antifungal, antibacterial |
| Ginseng | *Panax ginseng* | Fatigue, stress |
| Aspirin | *Salix alba* | Anti-inflammatory, analgesic, antipyretic |
| Quinine | *Cinchona spp.* | Antiparasitic |
| Echinacea | *Echinacea purpurea* | Immunomodulator |
| Ginkgo | *Ginkgo biloba* | Antioxidant, Anti-inflammatory, stress, |
| Garlic | *Allium sativum* | Anti-inflammatory, antihypertensive, antihyperlipidemic, respiratory infections |
| Cinnamon | *Cinnamomum zeylanicum* | Antimicrobial, Anti-inflammatory, immunostimulant, antioxidant, antihyperlipidemic |
| Turmeric | *Curcuma longa* | Anti-inflammatory, antioxidant, antimicrobial,  anticancerous |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Feed additives** | **Age** | **Treatment Effects (%, Compared to Control)** | | | **References** |
|  |  | **GIW** | **FI** | **FCR** |  |
| 0.5% Garlic powder | Upto 42 days | 7.97 | 1.18 | 7.22 | (Sharma et al. 2023) |
| 0.1% Cinnamon extract | Upto 42 days | 4.50 | 0.43 | 5 | (Sharma et al. 2023) |
| 0.1% cinnamon extract + 0.5% garlic powder | Upto 42 days | 7.20 | 1.15 | 6.66 | (Sharma et al. 2023) |
| *Spirulina plantensis* Algae 3% | Upto 35 days | 1.41 | 0.27 | -1.12 | (Ahmed et al. 2022) |
| *Spirulina plantensis* Algae 6% | Upto 35 days | 7.19 | 2.98 | -3.93 | (Ahmed et al. 2022) |
| Vegetable waste (cabbage 25%, cauliflower 50%, mustard 25%) 15 % | Upto 25 days | 19.19 | 30.09 | 9.3 | (Fitasari and Mushollaeni 2020) |
| CLA4(4% conjugated linoleic acid source containing 60% CLA methyl esters) | Upto 47 days | -0.77 | -0.50 | 0 | (Sirri et al. 2003) |
| Probiotic (Biomin Imbo 3 ×108cfu/g) at 0.15%, 0.075% and 0.0375% in starter, grower and finisher diets respectively. | Upto 49 days | 26.79 | -5.85 | -25.87 | (Taklimi et al. 2012) |
| *Achyranthes japonica* extract at 100mg/kg diet containing (flavanoid, polyphenol & saponin) | Upto 35 days | 3.5 | −2.4 | −6.2 | (Park and kim 2019) |

**Table 2: Growth performance of feed additives**

**Figure.1 Emerging nutraceuticals for better poultry production **