Use of Natural feed Additives to Control Important Infectious Diseases of Poultry

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Abstract

Infectious diseases pose significant challenges to the poultry industry because they damage both bird health and operational efficiency and economic prosperity. Natural feed additives have gained increased attention as substitute disease control approaches since consumers started demanding antibiotic-free poultry products and antimicrobial resistance became a crucial concern. The chapter examines the immunity-enhancing and pathogen-reducing properties of plant-derived compounds and probiotics, prebiotics, essential oils, organic acids and enzymes. These naturally sourced additives demonstrate antimicrobial properties along with anti-inflammatory effects and immunomodulatory functions for reducing four main infectious diseases affecting poultry: coccidiosis, salmonellosis, colibacillosis, and necrotic enteritis. Studies on their modes of action show that they can enhance gut integrity, prevent pathogen colonization, and alter the microbiota to favor good bacteria. The chapter also looks at environmental factors, dosage, and synergistic combinations that affect these compounds' effectiveness. The relevance of natural feed additives as a component of a comprehensive, sustainable disease management strategy in chicken production is highlighted by the presentation of recent research and field applications. The focus is on coordinating these interventions with the One Health framework in order to decrease the use of antibiotics, protect animal welfare, and guarantee consumer food safety.

Keywords: Probiotics, Prebiotics, Colibacillosis, Bioactive, Phytogenic, Microbiota

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Introduction

In previous years, the demand for meat products and chicken meat has increased. With over 137 million tons in 2020, chickens are produced worldwide, chicken is the most widely consumed meat. Therefore, consumption of animal protein, human nutrition, and global food security are all greatly influenced by the chicken sector (Rashid et al., 2020). The health and performance of chickens have significantly improved in recent years. The primary component of the chicken industry is feed, which exposes the gastrointestinal tract to a variety of substances that may have an impact on gut health. The gastrointestinal tract is thought to be an extremely active and complicated organ that is essential to gut health. Numerous stresses may have a detrimental effect on the gut ecosystem's balance, which in turn may affect the health and productivity of chickens. Stressors that affect gut health and increase susceptibility to disease, e.g heat stress and GI dysbiosis, are seen as significant hazards to the chicken business. When these stressors are reduced, gut of healthy animals can effectively by nutrients digestion and absorption (Carrasco et al., 2019).

Promotors of growth for antibiotics were formerly used to manage GI infections and lessen the impact of stresses on gut health. However, because of growing public awareness of antibiotics' detrimental effects on human health, bacterial resistance, and food safety concerns, restrictions have been placed on the usage of antibiotics in the production of chicken. Due to this circumstance, scientists and the poultry industry are investigating AGP substitutes while concentrating on creating more long-lasting dietary interventions to enhance the GI flora & general health of chickens. PFAs have become popular as AGP substitutes and offer enormous promise in the chicken sector (Cottrell et al., 2022). To check the effect of different natural feed additives in different infectious diseases of poultry. To check the absorption of natural feed additives at gut level. To check the immunity and growth level of poultry.

Herb licorice (*Glycyrrhiza glabra*)

It is a well-known traditional medicine plant that is a member of the *Fabaceae* family of legumes. It is widely utilized in the pharmaceutical industry, as a food preservative and flavoring, as well as for commercial uses (Alagawany et al., 2019). These are manufactured by sweet root of many *Glycyrrhiza* species; however, the processes of planting and harvesting alter the composition of a number of the plant's physiologically important components (Pastorino et al., 2018). Phytochemical study revealed that sugars, glucose, amino acids, ascorbic acid, tannins, choline, coumarins, phytosterols, and a few additional sour or acidic substances were the primary components of licorice extract (LE). *Glycyrrhizin* (Figure 1), glycyrrhetinic acid, and licorice acid were examples of triterpene saponins. Liquiritin, isoflavonoids, and formononetin were examples of flavonoids (Karahan et al., 2016). Because of its numerous positive health effects, such as its immunomodulatory, antibacterial, antioxidant, anti-inflammatory, antidiabetic, antiviral and radical-scavenging properties, licorice is a replacement option that has been found to be beneficial (Damle, 2014). Pictorial representation of the *Glycyrrhiza glabra herb*, its root and extract is presented in below (Alagawany et al., 2019).

Fig. 1: Pictorial representation of the *Glycyrrhiza glabra herb*, its root and extract

Cinnamon

Cinnamon belongs to the genus *Cinnamomum* (*Lauraceae* family) which contains more than 250–300 aromatic evergreen shrubs and plant trees. Only a small number of these species, such as *Cinnamomum zeylanicum, C. cassia, C. burman, and C. loureiori*, have substantial economic value as common spices globally. About 2.33 lac metric tons of cinnamon are produced annually; most of this crop is grown in Madagascar, China, India, Vietnam, Indonesia, and Sri Lanka. Effect of cinnamon on poultry gut health is described in below (Ali et al., 2021)

Poultry gut Health

Strong gut health develops in poultry through effective immune system development, adequate feed, water, and electrolyte balance digestion and absorption in the GI tract. The ecology in chicken's gut is essential for removing pathogens and poisons from the digestive system. The gut microbial environment is influenced by a wide range of elements, such as feed additives (such as organic acids, prebiotics, probiotics, enzymes, and photobiotics), feed composition, genetics, heat stress, and chicken farm feeding techniques. These elements significantly affect the GI-microbiome and health of chickens (Nawab et al., 2018). It is commonly acknowledged that the state of the gut affects how well chickens perform. The ideal state of health includes the intestinal tract's physiological functions functioning properly, morphological integrity, an effective immune system, developed barrier functions, energy balance, tissue metabolism, sustained inflammatory balance, and an adequate amount of microbiota to carry out desired tasks in the gut.

The composition and activity of the intestinal microbiota affect the health of chickens. Throughout the chicken's growth period, the accession and intestinal microbiota's maturation plays a significant role in modulating physiological functions. In order to sustain the GI homeostasis & the development of the intestinal epithelium. These tasks are essential to the poultry birds' optimal energy usage and extraction efficiency (Carrasco et al., 2019). Poultry birds' intestinal microbiota is a composite community made up of a variety of microbes. Chicken intestinal microbiota is often dominated by hundreds of species of Actinobacteria, Fusobacteria, and Proteobacteria at phylum level. Digestive tract of chicken is divided into several portions, including the colon, ileum, gizzard, and crop. Each of these areas has a unique habitat and physiological function that starts a complex microbial ecosystem in a specific location. There are 100 trillion cells and 500–1000 different types of bacteria in the gastrointestinal tract (GIT) (Iqbal et al., 2020). In varied amounts, bacteria, protozoa, and fungi make up the ecology in the fowl stomach. In chicken birds, the concentration of microbiota fluctuates along the digestive system, reaching its greatest at the distal parts. The intestinal epithelium engages in cellular signaling and possesses tight connections between its cells to stop microbial invasion.

Numerous studies have indicated that oxidative stress, that results in breakdown of tight junctions, the intestinal epithelial barrier, the intestinal mucosa, and lipid peroxidation, is caused by interactions between the mucosa and pathogenic bacteria or their toxins. Intake of lower feed, digestion, and nutrient absorption in the GI tract led to poorer growth efficacy in the diseased poultry birds. The intestinal mucosa is preserved and free radicals are lessened when dietary antioxidant chemicals are added to feed. Therefore, developing a practical strategy to reduce oxidative stress in the chicken sector is essential. The addition of bioactive substances to poultry feed enhances immunity, antioxidant capacity, and overall health. Very active substances found in cinnamon include phenolics and essential oils (EOs), that have strong anti-inflammatory, antioxidant, and anti-microbial properties and function as buffers against oxidative damage in the chicken digestive system.

Coccidiosis

A parasitic intestinal infection known as poultry coccidiosis is brought on by protozoan parasites belonging to various species of Eimeria. The most common disease among broiler chickens is coccidiosis, which is estimated to cause up to $3 billion in annual economic losses globally. The parasites have an oral-fecal life cycle with no intermediate host. Depending on the exposure levels and environmental factors, they can cause severe disease and death. Even though it typically affects young birds, older animals that haven't built up an immune to the illness may still get coccidiosis (Calik et al., 2019; Cunha et al., 2020). In order to address some important issues in the field, the utilization of dietary nutrients and nutritional supplements as a source of reducing Eimeria infection and enhancing the health of GI tract of broilers was considered.

Investigating this (Bortoluzzi et al., 2020), thefocus was on the potential significance of micro-minerals and the GIT absorption for altering the microbiology, immunology, and intestinal physiology of broiler chickens during an Eimeria infection. When Zn was fed to broilers afflicted with Clostridium perfringens and coccidia, they demonstrated positive benefits, improved performance, and reduced the inflammatory response. Zn also affects the ileal microbiome, which enhances the health of broiler chickens' guts. Additionally, it has been demonstrated that adding Cu and Mn to feed during an Eimeria infection improves feed conversion and modifies the immunological response (Cunha et al., 2020). Similarly (Kiarie et al., 2019) We concentrated on examining how yeast byproducts and feed enzymes affect coccidial infection. The use of these additions as a supplemental or alternative approach to infection control was covered by the writers. Several research they cited demonstrated that using entire yeast or its byproducts as nucleotides or cell wall-associated nutritional catalysts enhanced cellular and humoral immune responses, which would be essential for increasing the effectiveness of coccidial vaccines.

Additionally, two unique study studies on dietary supplements were released here. (Stefanello et al., 2020) explored application of a mixture of essential oils and shielding the organic acids to enhance the health of broilers afflicted with Clostridium perfringens and Eimeria spp. Compared to growth promoter (AGP), the combination of protected organic acids and essential oils enhanced intestinal health, nutritional digestibility, and growth performance in the treated animals. This suggests that the combination could be a great substitute in AGP-free programs.

Similar to this, (Calik et al., 2019) he demonstrated how feeding broiler chickens challenged with coccidiosis with direct feed microbial (DFM) dietary supplement improved their immune response, altered their intestinal architecture, and improved their performance (Table 1). After receiving the addition, the ileal villus area increased, the duodenum and jejunum lesions decreased, and the chickens' body weight increased. The ileum also showed increased expression of IL-1β and IFN-γ, suggesting that broiler feed containing microbes may be a promising method for enhancing chicken health.

ND Virus

Newcastle disease (ND) is a highly contagious disease that affects birds worldwide, especially farmed poultry. The virus that causes it belongs to the paramyxovirus family. It can swiftly spread to huge populations of birds and cause illness and death (Abdu et al., 2006).

There have been reports of formaldehyde being used as an antibacterial. Formaldehyde has seen a great deal of use recently, particularly in cold sterilization, toxin and vaccine inactivation, agriculture, and egg incubators (Levine et al., 2007). In the latter case, the virus capsid proteins are enough undamaged to be immunogenic, triggering an immune response, even though the virus particles are destroyed and unable to multiply. This study looked at how a formaldehyde antimicrobial feed addition affected the immunological indices of hens who were experimentally infected with this strain of the Newcastle Disease virus. Scientists studying poultry these days are wondering how farmers can raise birds without using antibiotics and other medications. The use of natural remedies is becoming more popular. The enzymatic activity of certain plants and their extracts can have anthelmintic, coccidiostatic, or antimicrobial effects in addition to improving feed intake. Pakistan has grown medicinal plants throughout a huge region and in a variety of climates. These plants all have ingredients that can be applied to poultry in one manner or another. Neem (*Azadirachta indica*), often known as "Indian Lilac" or "Margosa," is one of these plants and a member of the tribe *Melieae*, subfamily *Meloideae*, and family *Meliaceae*.

It is grown throughout Sindh, southern Punjab, lower Baluchistan, and the southern NWFP in Pakistan. Neem *(A. indica)* is one among the trees for which there is presently a great deal of study being conducted worldwide. There have been reports of compounds including quercetin, azadiractin, nimbin, and nimbindin being present in different portions of the neem tree ("Makeri HK, Maikai VA, Nok JA (2007),"). *A. indica* is a rapidly growing evergreen tree that may offer broilers nutritional and therapeutic benefits. When broilers are administered neem leaf extract in water, they exhibit increased weight gain and better nutrient conversation efficiency. Neem also has a significant impact in bolstering the body's immune system. When neem is added to poultry meals, an increase in antibodies against the viruses that cause infected bursal disease and new castle has been noted ("Durrani FR, Sultan A, Akhtar S, Jan M, Chand N, Durrani Z (2008),").

It has been found that a 10% water-based extract of neem leaves has antiviral activities against Newcastle disease virus (NDV), infectious bursal diseases (IBD), and chicken pox. It also greatly increases the generation of antibodies against IBD and NDV. Therefore, the purpose of the current study was to document how A. indica affected the commercial broiler population's immunity to infectious bursal illness and New castle.

Avian Influenza (AI)

Avian influenza virus (AIV) infection has been shown to be a major contributor to significant economic losses in poultry farms across the globe, as evidenced by the high death rate and sharp decline in egg production. In addition, thousands of people have died from AIV infection, many of whom had direct contact with the poultry industry(Dhingra et al., 2018). In fact, the application of antiviral medication families, including neuraminidase and hemagglutinin inhibitors, to combat influenza viruses in humans restricts their usage in animals and poultry in order to minimize the emergence of drug resistance. Furthermore, the commercial use of those medications appears to be highly costly and out of reach for many nations (Abdelwhab & Hafez, 2012).

Herbal remedies and traditional plants have long been used to treat and prevent a wide range of illnesses and health issues, including heavy metal poisoning, on a small-scale basis. (Khafaga, Abd El-Hack, et al., 2019; Khafaga, Noreldin, et al., 2019), and viral disease (Mahmood et al., 2018; Oyuntsetseg et al., 2014; Sun et al., 2019). Because herbal remedies are widely available and simple to incorporate into a diet, they are becoming increasingly significant in studies aimed at combating influenza (El-Hamid et al., 2018). Numerous research examined the safety and effectiveness of various herbal medicines against AI in vitro, evaluating the effectiveness of extracts, plant parts, or whole plant blends. Additional in vivo research was carried out on mice models and many types of poultry using these results. Use of herbal plants for the preventive and management or check the AI virus actually depends on in vitro research, but in vivo research is even more crucial, commercially.

Table 1: Representation of Glycyrrhiza glabra herb, root, and extract (Alagawany et al., 2019)

Natural Additive	Target Disease	Dosage	Reported Effects	Refrence
Garlic(Allium Sativum)	Coccidiosis	1% in feed	Reduced oocyst Shedding and Mortality	Al-Mufarrej et al., 2019
Licorice (Glycyrrhiza Glabra)	Newcastle Disease	0.5% in Water	Improved Antibody Titer and Survival Rate	Alagawany et al., 2019
Turmeric (Curcuma Longa)	Avian Influenza (AI)	0.3% in feed	Enhanced Immune Response and Resistance	Rahmani et al., 2020

Effects of Adjuvant

Sargassum pallidum polysaccharides (SPP) (Turner)

SPP's effectiveness as an adjuvant for inactivated NDV, AIV, and infectious bronchitis virus (IBV) vaccinations in hens was evaluated by (Li et al., 2012). The standard oil adjuvant vaccinations and the vaccines with 10, 30, and 50 mg SPP/mL were compared in that study. At a dosage of 30mg/mL, serum antibody titers against the three viruses dramatically rose. Also, in every treatment group, there was an increase in T lymphocyte multiplication and CD+4 content.

Improvement of Immunity to Vaccination

Pleurotus ostreatus wastes (Oyster mushroom)

The effects of two different dosages of oyster mushroom powder (10 and 20 g/kg) added to the diet were compared to the effects of a prebiotic inclusion (1 g/kg A-Max®, mannan-oligosaccharides) on the humoral immune responses of Ross 308 male broiler chicks to NDV and AIV. When compared to the other treatments, the prebiotic-supplemented group's birds had the highest body weight and the lowest feed conversion ratio for the course of the full study period, which lasted for 42 days.

Virgin coconut oil

An experiment did by (Yuniwarti et al., 2012) who, over course of 4 weeks, examined the effects of VCO at multiple dosages (0, 5, 10, and 15 mL/kg feed). The birds were split into 8 groups, four of which received AI vaccinated while the other four unvaccinated. In comparison to non-vaccinated chicks receiving the exact amount of VCO, the results demonstrated an increase in the NO. of lymphocytes and Th-CD4 in AI-vaccinated birds that received 10 mL/kg of food.

Nevertheless, a decrease in these numbers was noted in poultry fed a diet containing 15 milliliters of VCO per kilogram. This increase in lymphocyte proliferation may be attributed to the production of phospholipids and stimulation of IL-2 receptors by VCO; consequently, an enhancement in T lymphocytes stimulated by VCO would result in an increase in T-helper cells, which would in turn stimulate B lymphocyte cells to produce more antibodies. Conversely, the drop in lymphocyte count in chicks fed a meal containing 15 milliliters of VCO per kg could be explained by modifications to the lipid structure and fluidity of the membrane, which in turn lead to a reduction in sensitivity of receptors of Interleukins-2 and reduction of lymphocyte enhancement.

Aloe vera (AV)

The effects of adding varying amounts of AV (0.5%, 0.75%, and 1%) to drinking water as a potential antibiotic AGP and seeing how this affected the immune system and growth performance of broiler chickens were investigated.

According to (Shokraneh et al., 2016) all treatments had no effect on antibody titers against AIV, despite the fact that adding AV at level 1% produced higher antibody titers against SRBC than other groups ($P<0.05$). An additional study used one-day-old Ross chicks as supplements and gave them 3% of AV in drinking water, 3% of powder of garlic in food, and a mutual of 1.5% of AV in drinking water and 1.5% of garlic powder in diet.

NDV and AIV antibody titers did not differ significantly between control and treated chicks; however, the combined AV-garlic group showed strong result of antibody titers of the both viruses on days 18 & 28 (Fallah, 2014).

Allium sativum powder (Garlic)

It was assessed if broiler chicks' diets with 1 or 3% fresh garlic powder will enhance their immune responses to the AIV H9N2 vaccine. The findings indicated that the administration of the H9N2 vaccine or its removal had no effect on antibody titers, indicating that dietary garlic was ineffective in inducing a humoral response in hens against the Avain I Virus vaccine (Jafari et al., 2009). Moreover, broiler hens fed supplemented diet with 2 and 4 g/kg of powder of garlic at the ages of 18 and 28 days did not exhibit any appreciable increase in humoral antibodies against AI- Virus and ND Virus (Toghyani et al., 2011).

In opposing, (Eid & Iraqi, 2014) resulted that garlic powder supplementation at a rate of 100, 150, or 200 g/ton showed the greatest beneficial effect on AI-Virus and ND Virus's antibody titers, with a significant influence ($P<0.001$) on these levels.

Azadirachta indica (Neem)

Neem can have a positive influence on broiler immune responses without having any known detrimental effects on performance of growth (Mahmood et al., 2018). make it clear that 1 day-old broiler chicks were given a diet that included 7 or 12 grams of neem fruit powder per kilogram, as opposed to an antibiotic growth promoter called flavophospholipol. Compared to the control diet and the flavophospholipol diet, treatment with 7 g neem/kg enhanced antibody titers against SRBC more than 12 g neem/kg and influenza virus. At this concentration, all performance metrics improved concurrently (Landy, Ghalamkari, & Toghyani, 2011; Landy, Ghalamkari, Toghyani, et al., 2011).

Conclusion

In light of growing antibiotic resistance and customer desires for antibiotic-free products, natural feed additives offer a viable and sustainable strategy for controlling infectious illnesses in chicken. This chapter describes how a variety of natural chemicals, such as organic acids, essential oils, probiotics, prebiotics, and phytobiotics, have shown effective in avoiding and controlling important chicken infections. By strengthening immune responses, lowering the pathogenic burden, and improving gastrointestinal health, these additions increase the general resilience and production of birds. Their modes of action, which include microbiota modification, competitive exclusion, and antimicrobial peptide activation, provide multifaceted protection without the negative effects of synthetic medications. Nonetheless, proper formulation, administration, and integration with good husbandry techniques are necessary for consistent results. Despite encouraging studies, more extensive field testing and standardization are needed to maximize their application. Encouragement of innovation, farmer education, and robust regulatory frameworks should all be part of the shift to natural feed additives. In the end, the effective use of these substitutes not only promotes sustainable management of poultry health but also supports international initiatives to fight antibiotic resistance in accordance with the One Health paradigm. Their incorporation into chicken diets has enormous potential to advance public health security, environmental sustainability, and animal health

References

Abdelwhab, E. M., & Hafez, H. M. (2012). Insight into alternative approaches for control of avian influenza in poultry, with emphasis on highly pathogenic H5N1. *Viruses*, *4*(11), 3179-3208.

Abdu, P. A., Tekdek, L. B., Umoh, J. U., Usman, M., & Oladele, S. B. (2006). Newcastle disease in Nigeria. *Nigerian Veterinary Journal*, *27*(2), 23-32.

Alagawany, M., Elnesr, S. S., & Farag, M. R. (2019). Use of liquorice (Glycyrrhiza glabra) in poultry nutrition: Global impacts on performance, carcass and meat quality. *World's Poultry Science Journal*, *75*(2), 293-304.

Alagawany, M., Elnesr, S. S., Farag, M. R., Abd El-Hack, M. E., Khafaga, A. F., Taha, A. E., ... & Dhama, K. (2019). Use of licorice (Glycyrrhiza glabra) herb as a feed additive in poultry: Current knowledge and prospects. *Animals*, *9*(8), 536.

Ali, A., Ponnampalam, E. N., Pushpakumara, G., Cottrell, J. J., Suleria, H. A., & Dunshea, F. R. (2021). Cinnamon: A natural feed additive for poultry health and production—A review. *Animals*, *11*(7), 2026.

Al-Mufarrej, S. I., Al-Baadani, H. H., et al. (2019). The effect of garlic powder on performance and immunity in broilers. *Journal of Animal and Plant Sciences*, 29(3), 632–640.

Bortoluzzi, C., Vieira, B. S., & Applegate, T. J. (2020). Influence of dietary zinc, copper, and manganese on the intestinal health of broilers under Eimeria challenge. *Frontiers in Veterinary Science*, *7*, 13.

Clik, A., Omara, I. I., White, M. B., Li, W., & Dalloul, R. A. (2019). Effects of dietary direct fed microbial supplementation on performance, intestinal morphology and immune response of broiler chickens challenged with coccidiosis. *Frontiers in Veterinary Science*, *6*, 463.

Cottrell, J. J., Le, H. H., Artaiz, O., Iqbal, Y., Suleria, H. A., Ali, A., & Dunshea, F. R. (2021). Recent advances in the use of phytochemicals to manage gastrointestinal oxidative stress in poultry and pigs. *Animal Production Science*, *62*(12), 1140-1146.

Cunha, A. F. D., Santin, E., & Kogut, M. (2020). Poultry coccidiosis: strategies to understand and control. *Frontiers in Veterinary Science*, *7*, 599322.Damle, M. (2014). Glycyrrhiza glabra (Liquorice)-a potent medicinal herb. *International Journal of Herbal Medicine*, *2*(2), 132-6.

Dhingra, M. S., Artois, J., Dellicour, S., Lemey, P., Dauphin, G., Von Dobschuetz, S., & Gilbert, M. (2018). Geographical and historical patterns in the emergences of novel highly pathogenic avian influenza (HPAI) H5 and H7 viruses in poultry. *Frontiers in Veterinary Science*, *5*, 84.

Diaz Carrasco, J. M., Casanova, N. A., & Fernández Miyakawa, M. E. (2019). Microbiota, gut health and chicken productivity: what is the connection?. *Microorganisms*, *7*(10), 374.

Durrani, F. R., Sultan, A., Jan, M., Chand, N., & Durrani, Z. (2008). Immunomodulatory and growth promoting effects of Neem (Azadirachta indica) leaves infusion in broiler chicks. *Sarhad Journal of Agriculture*, *24*(4), 655-659.

Eid, K. M., & Iraqi, M. M. (2014). Effect of garlic powder on growth performance and immune response for newcastle and avian influenza virus diseases in broiler of chickens. *Animal Biotechnology (Poultry and Fish)*, *1*, 7-13.

El-Hamid, H. S. A., Ellakany, H. F., Elbestawy, A. R., Seliem, A. A., & Khalil, H. S. (2018). In vitro antiviral activity of commercial products of herbal extracts against highly pathogenic avian influenza (H5N1) virus. *Alexandria Journal of Veterinary Sciences*, *56*(1).

Fallah, R. (2014). Effects of supplementing Aloe vera gel and garlic powder on blood biochemical parameters and immune response of broiler. *Journal of Medicinal Plants Research*, *8*, 1035-1039.

Iqbal, Y., Cottrell, J. J., Suleria, H. A., & Dunshea, F. R. (2020). Gut microbiota-polyphenol interactions in chicken: A review. *Animals*, *10*(8), 1391.

Jafari, R. A., Ghorbanpoor, M., & Hoshmand Diarjan, S. (2009). Study on immunomodulatory activity of dietary garlic in chickens vaccinated against avian influenza virus (subtype H9N2). *International Journal of Poultry Science*, *8*, 401-403.

Karahan, F., Avsar, C., Ozyigit, I. I., & Berber, I. (2016). Antimicrobial and antioxidant activities of medicinal plant Glycyrrhiza glabra var. glandulifera from different habitats. *Biotechnology & Biotechnological Equipment*, *30*(4), 797-804.

Khafaga, A. F., Abd El-Hack, M. E., Taha, A. E., Elnesr, S. S., & Alagawany, M. (2019). The potential modulatory role of herbal additives against Cd toxicity in human, animal, and poultry: a review. *Environmental Science and Pollution Research*, *26*, 4588-4604.

Khafaga, A. F., Noreldin, A. E., & Taha, A. E. (2019). The adaptogenic anti-ageing potential of resveratrol against heat stress-mediated liver injury in aged rats: Role of HSP70 and NF-kB signalling. *Journal of Thermal Biology*, *83*, 8-21.

Kiarie, E. G., Leung, H., Akbari Moghaddam Kakhki, R., Patterson, R., & Barta, J. R. (2019).

Rahmani, A. H., Aly, S. M., et al. (2020). Curcumin: A natural modulator of immune responses in avian species. *Veterinary World*, 13(9), 1890–1895.

Utility of feed enzymes and yeast derivatives in ameliorating deleterious effects of coccidiosis on intestinal health and function in broiler chickens. *Frontiers in Veterinary Science*, *6*, 473.

Landy, N., Ghalamkari, G. H., & Toghyani, M. (2011). Performance, carcass characteristics, and immunity in broiler chickens fed dietary neem (Azadirachta indica) as alternative for an antibiotic growth promoter. *Livestock Science*, *142*(1-3), 305-309.

Landy, N., Ghalamkari, G. H., Toghyani, M., & Moattar, F. (2011). The effects of Echinacea purpurea L.(purple coneflower) as an antibiotic growth promoter substitution on performance, carcass characteristics and humoral immune response in broiler chickens. *Journal of Medicinal Plants Research*, *5*(11), 2332-2338.

Levine, M. M., Ferreccio, C., Black, R. E., Lagos, R., Martin, O. S., & Blackwelder, W. C. (2007). Ty21a live oral typhoid vaccine and prevention of paratyphoid fever caused by Salmonella enterica Serovar Paratyphi B. *Clinical Infectious Diseases*, *45*(Supplement_1), S24-S28.

Li, L. J., Li, M. Y., Li, Y. T., Feng, J. J., Hao, F. Q., & Zhang, L. (2012). Adjuvant activity of Sargassum pallidum polysaccharides against combined Newcastle disease, infectious bronchitis and avian influenza inactivated vaccines. *Marine Drugs*, *10*(12), 2648-2660.

Mahmood, M. S., Amir, H. W., Abbas, R. Z., Bilal Aslam, B. A., & Azhar Rafique, A. R. (2018). Evaluation of antiviral activity of Azadirachta indica (Neem) bark extract against Newcastle disease virus. *Pakistan Veterinary Journal, 38*(1), 25-28.

Makeri, H. K., Maikai, V. A., & Nok, J. A. (2007). Effect of topical application of neem seed (Azadiracta indica) extract on sheep infested with Amblyomma variegatum. *African Journal of Biotechnology*, *6*(20).

Nawab, A., Ibtisham, F., Li, G., Kieser, B., Wu, J., Liu, W., & An, L. (2018). Heat stress in poultry production: Mitigation strategies to overcome the future challenges facing the global poultry industry. *Journal of Thermal Biology*, *78*, 131-139.

Oyuntsetseg, N., Khasnatinov, M. A., Molor-Erdene, P., Oyunbileg, J., Liapunov, A. V., Danchinova, G. A., & Chimedragchaa, C. (2014). Evaluation of direct antiviral activity of the Deva-5 herb formulation and extracts of five Asian plants against influenza A virus H3N8. *BMC Complementary and Alternative Medicine*, *14*, 1-9

Rashid, Z., Mirani, Z. A., Zehra, S., Gilani, S. M. H., Ashraf, A., Azhar, A., & Galani, S. (2020). Enhanced modulation of gut microbial dynamics affecting body weight in birds triggered by natural growth promoters administered in conventional feed. *Saudi Journal of Biological Sciences*, *27*(10), 2747-2755.

Shokraneh, M., Ghalamkari, G., Toghyani, M., & Landy, N. (2016). Influence of drinking water containing Aloe vera (Aloe barbadensis Miller) gel on growth performance, intestinal microflora, and humoral immune responses of broilers. *Veterinary World*, *9*(11), 1197.

Stefanello, C., Rosa, D. P., Dalmoro, Y. K., Segatto, A. L., Vieira, M. S., Moraes, M. L., & Santin, E. (2020). Protected blend of organic acids and essential oils improves growth performance, nutrient digestibility, and intestinal health of broiler chickens undergoing an intestinal challenge. *Frontiers in Veterinary Science*, *6*, 491.

Sun, N., Sun, P., Xie, N., Khan, A., Sun, Y., Fan, K., & Li, H. (2019). Antiviral and immunomodulatory effects of dipotassium glycyrrhizinate in chicks artificially infected with infectious bursal disease virus. *Pakistan Veterinary Journal*, *39*, 43-48.

Toghyani, M., Toghyani, M., Gheisari, A., Ghalamkari, G., & Eghbalsaied, S. (2011). Evaluation of cinnamon and garlic as antibiotic growth promoter substitutions on performance, immune responses, serum biochemical and haematological parameters in broiler chicks. *Livestock Science*, *138*(1-3), 167-173.

Yuniwarti, E. Y. W., Asmara, W., Artama, W. T., & Tabbu, C. R. (2012). The effect of virgin coconut oil on lymphocyte and CD4 in chicken vaccinated against avian influenza virus. *Journal of the Indonesian Tropical Animal Agriculture*, *37*(1), 64-69.