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Review Article

TURMERIC'S ROLE AS A NATURAL ANTIBIOTIC AGAINST IMMUNOSUPPRESSIVE DISEASES IN POULTRY

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Abstract: *The poultry industry, a vital constituent of global food production, poses formidable threats from immunosuppressive illnesses that compromise poultry health, output, and economic sustainability. Due to various infectious and non-infectious agents, these immunosuppressive provisions significantly heighten birds' susceptibility to secondary infections and undermine the efficacy of vaccination. Poultry mortality and morbidity can be caused by non-infectious factors such as environmental stressors and nutritional deficiencies. The overuse of antibiotics in poultry production raises concerns about antibiotic resistance and public health, leading to the search for natural alternatives. Turmeric, scientifically known as Curcuma longa, has emerged as a promising solution due to its various attributes, including antimicrobial, antioxidant, anti-inflammatory, and immunomodulatory properties. It is poised to effectively supplant synthetic antibiotics in poultry, thus mitigating the risks to public health. This review paper investigates the role of turmeric as a natural antibiotic against immunosuppressive diseases in poultry. It comprehensively explores the multifaceted causes of immunosuppression in poultry, encompassing environmental stress, nutritional factors, and infectious agents. Furthermore, the article explores how turmeric can combat various issues and highlights its potent antimicrobial, anti-inflammatory, and antioxidant properties. Turmeric has been shown to enhance growth, boost immune function, and mitigate the adverse effects of stress, making it a valuable and sustainable solution for the poultry industry. By alleviating the risk of immunosuppression, turmeric safeguards avian health and augments the industry's overall success. This paper underscores the significance of embracing natural remedies like turmeric to uphold poultry health and well-being while diminishing reliance on synthetic antibiotics.*

Keywords: Immunity, Immunosuppression, Immunosuppressive Agents, Turmeric

Introduction

Poultry production is a crucial source of animal protein worldwide. The poultry industry facing a significant challenge characterized by a decrease in productivity and an increase in mortality rates, primarily attributed to infectious diseases. These diseases threaten the poultry's health and well-being and result in substantial economic losses (Hafez & Attia, 2020). A significant threat to poultry health is immunosuppressive diseases in which a weak immune system increases susceptibility to infections and reduced growth rates**,** such as viral, fungal, and protozoal pathogens (Aggarwal & Harikumar, 2009). Besides infectious diseases, environmental and nutritional factors contribute to birds' immunosuppression. Environmental factors such as high temperature, humidity, and poor ventilation cause immunosuppression in birds, leading to respiratory infections and reducing the ability to cope with stress (Munir et al., 2017). Nutritional factors such as mineral and vitamin deficiencies impair the immunity of birds (Al-Sultan, 2003). Antibiotics have been used to control infectious diseases in poultry. However, this practice emerges as a threat to public health due to the development of antibiotic-resistant bacteria caused by the overuse of antibiotics (Ferri et al., 2017). There is a significant concern about using natural products instead of antibiotics to control infectious diseases in poultry (Shende et al., 2021). Turmeric (Curcuma longa), known for its medicinal properties, is a widely used spice in Indian and South Asian cuisine. Curcumin, an active compound in turmeric, possesses anti-inflammatory, antimicrobial, and antioxidant properties (Casewell et al., 2003). Studies have shown the role of turmeric in the poultry industry as a natural antibiotic against various infectious diseases caused by viruses, bacteria, fungus, and protozoa, along with immunomodulatory effects to prevent immunosuppression in birds caused by immunosuppressive diseases (Zorofchian Moghadamtousi et al., 2014). The use of turmeric in poultry is an area of active research.
This article aims to review the current knowledge relative to the potential use of turmeric against immunosuppressive diseases in poultry.

Turmeric:
Turmeric is rich in bioactive compounds used medicinally as human remedies and non-medicinally as a spice (Shende et al., 2021). There are lots of antibiotics available

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commercially. Turmeric is considered a natural, non-toxic antibiotic and an ideal food additive for diet use (Shende et al., 2021). The composition of turmeric is 69.4% carbohydrates, 6.3% protein, 5.1% fat, 3.5% minerals, and 13.1% moisture (Shi, n.d.). Phenolic compounds like curcumin, demethoxycurcumin, bisdemethoxycurcumin, and tetrahydrocurcumin metabolites are also present in turmeric (E. Wright et al., n.d.). These phenolic compounds possess antioxidant, antibacterial, antiviral, antifungal, antihypertensive, anti-inflammatory, and anti-carcinogenic properties (Masuda et al., 2001). The effect of turmeric on broilers, concerning enhanced weight and growth rate, has been studied (Mondal et al., 2015). Turmeric improves the digestive system by stimulating intestinal lipase, maltase, and sucrose activity, and pancreatic amylase, lipase, chymotrypsin, and trypsin secretion. It also positively affects egg production in hens. Increased yolk weight and index from turmeric supplementation have been studied (Anusha et al., 2018).

Importance of the Immune System in Avian Health and Management:

The immune system is vital to show the excellent health status of the bird. It helps to identify disease-causing agents and differentiates them from body cells and tissues. The immune system comprises specific and non-specific types of immune systems (Fellah et al., 2014). It is the non-specific immune system in which birds fight diseases, such as innate or inherent immunity (Fellah et al., 2014). It includes anatomic features, genetic factors, body temperature, normal microflora, respiratory cilia, etc. (Jenkins et al., 2007). In the case of a non-specific immune system, good management practices should be done to maintain good bird health; like toxins in higher concentration or misuse of antibiotics (Dibner et al., 1998) result in disturbance to normal microflora, poor feed like deficiency in nutrients welcomes diseases causing agents to damage protective body organs (Lillehoj & Trout, 1996). Specific immunity is specificity and memory, which consists of cellular and non-cellular components. Antibodies are the non-cellular part of a particular immune system divided into three parts: IgA, IgG, and IgM (Dibner et al., 1998). These three components are produced by birds after disease (Fellah et al., 2014) or vaccination exposure. These components are made by a specific type of cells called B-lymphocytes. T-lymphocytes are a specific immune system's cellular part that produces particular cells, such as lymphokines.

Organs and cells involved in the immune system include the spleen, thymus, Bursa of Fabricius, and bone marrow, lymphoid cells in the gut, trachea, esophagus, Harderian gland, cecal tonsils, and circulating lymphocytes. Immunosuppression is the state in which the body's immune system is weakened. It is neither a disease nor has clinical signs. It is characterized by increased mortality, atrophy of lymphoid organs, poor performance (Fellah et al., 2014), etc. It can be caused by infectious agents or changes in management. However, the cause must be removed to prevent the loss of production and economic performance (Lillehoj & Trout, 1996).

Factors Contributing to Immunosuppression in Poultry:

Environmental factors

Most factors for immunosuppression in poultry are management factors like temperature stress, inadequate water or food supply, ammonia in the house, etc. (Nawab et al., 2018). Corticosterone is produced due to these stressors. High versus low corticosterone concentration in blood plasma is evidence of stress-related immunosuppression (Cross et al., 2024). The presence of fungal toxins in feed is also a point of environmental stress. Social stress can exacerbate disease. There is a study in which MDV-positive chickens were kept in stressful conditions by moving from one cage to another daily, and it was noted that the MDV-positive chickens moved daily to develop tumors more than those observed in low stressful conditions (Publications Manager, 2000). Tumors developed because there was high plasma corticosterone concentration due to social stress. There is a reduction in the impact of social anxiety on MD and other diseases if there is an inoculation of 11-beta hydroxylase-blocking chemicals, which involves the conversion of deoxycorticosterone to corticosterone in the adrenal gland (Ratnani et al., 2017). Inoculation of chickens with corticosterone results in the thymus, bursa, and spleen lymphoid depletion (Shini & Kaiser, 2009). There is a similarity between bacterial infections and corticosterone-induced lymphoid depletion due to the lesions in the bursa. It has been studied that chick quality is affected when there is a reduction in egg production and low levels of testosterone and progesterone in the yolk due to high levels of corticosterone (Henriksen et al., 2011). In addition, juvenile stress responses can be altered due to embryonic exposure to increased corticosterone levels (Haussmann et al., 2012). It has also been studied that using turmeric can relieve environmental stress in birds. Stressors like high temperature, ammonia, humidity (Barzegar & Moosavi-Movahedi, 2011), etc., cause oxidative stress in birds (Tuong et al., 2023). Oxidative stress occurs due to an imbalance between reactive oxygen species (ROS) production and the bird's antioxidant defences (Surai et al., 2019). ROS can cause cell death by damaging cell membranes, proteins, and DNA. Turmeric contains a phenolic compound called curcumin, which has antioxidant properties. Curcumin protects cell membranes from damage by scavenging free radicals and inhibiting lipid peroxidation. It supports the expression of superoxide dismutase (SOD) and glutathione peroxidase (GPx) genes involved in antioxidant defense (Barzegar & Moosavi-Movahedi, 2011). There are different studies on environmental stressors in birds. For example, a survey on broiler chicken with turmeric supplementation in feed increased the activity of antioxidant enzymes like SOD, GPx, and catalase and reduced lipid peroxidation levels in liver and muscle tissues. There was observed better performance, feed conversion ratio and meat quality. Turmeric can remove altitude stress in broilers.

Similarly, a study conducted on broilers at high altitudes with turmeric supplementation in feed resulted in an increase in body weight, feed intake, antioxidant enzyme activity, and reduction in malondialdehyde levels in liver and muscle tissues, which is a biomarker of lipid peroxidation (Johannah et al., 2018). Turmeric can also save the birds from pollutants. For this purpose, a study was conducted on layer hens exposed to toxicity were fed with a supplemented diet, which resulted in high egg production with improved egg quality by increasing the activities of antioxidant enzymes and decreasing the malondialdehyde levels in liver and egg yolk tissues (Damiano et al., 2022). Using turmeric as a natural antibiotic in poultry feed

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effectively improves growth performance under stressful conditions.

Nutritional factors:

Birds with well-nourished diets indeed show more competency towards disease resistance. There is a change in nutrient and energy intake with a change in feed intake (Hanson & Gluckman, 2014). Nutritionally deficient birds are unable to develop effective immune systems. However, both energy and nutrients are found in commercial poultry feed—immunosuppression in poultry results in decreased feed intake. Nutrient deficiencies such as vitamins, minerals, and amino acids cause immunosuppression in birds (Yunus et al., 2011a). Vitamin E is a cell membrane stabilizer **[25]**. There is ingestion of free radicals due to poorly stabilized fats, oils, and animal by-products, which are responsible for damaging cell membranes (Bondy & Pestka, 2000a). Most of the threat is for rapidly multiplying cell membranes, which are exposed to free radicals. Vitamin E can remove these radicals with the help of the immune system (Bondy & Pestka, 2000a). Vitamin E possesses a crucial immunoregulatory mechanism in modulating the arachidonic mechanism through lipoxygenase and cyclooxygenase pathways, which results in the synthesis of leukotrienes and prostaglandins, respectively (Yunus et al., 2011a). So, Vitamin E deficiency leads to an increase in free radicals, which is responsible for immunosuppression.

Vitamin C deficiency causes immunosuppression indirectly by lowering the speed of healing and increasing the effect of stress. It is essential for white blood cell synthesis and corticosterone non-synthesis during stress conditions (Bondy & Pestka, 2000a). Vitamin A is for antibody production and mucus membrane formation (Qureshi et al., 1998a). Vitamin A deficient bird behavior has been studied for less ND antibody production and T-cell response as well because its deficiency results in the emergence of various viral and bacterial diseases such as Newcastle disease, Infectious bronchitis, Coccidiosis, Necrotic enteritis, Mycoplasmosis, etc. (Cheng et al., 2006a), which are related with immunosuppression. These vitamins are essential for better performance and carcass traits. These vitamins protect the immune system, impacting hormones by decreasing their effects and oxidative damage and improving production and cell differentiation (Rezar et al., 2007a). Proper arginine concentration in feed is essential for the immune system as its metabolism increases nitric acid production from macrophages and nitric oxide production (Rezar et al., 2007a). Arginine possesses various vital roles, such as increased thymus weight and functions, lymphocyte mitogenesis, wound healing, and immunity against tumors (Pestka et al., 2004a). A high concentration of methionine in the diet is related to the immunosuppression. However, its deficiency and other ones like valine, threonine, riboflavin, pantothenic acid, pyridoxine, sodium chloride, zinc, and selenium have immunosuppression effects (Pestka et al., 2004a). Every amino acid, vitamin, mineral, and energy plays an important role. So, it is necessary to maintain their appropriate levels in feed to prevent immunosuppression in poultry. It has an active ingredient, "Curcumin," has various properties like antimicrobial, antioxidant, anti-inflammatory, and immunomodulatory effects (Boroumand et al., 2018). It has been used in the poultry industry for centuries. It can remove free radicals from the body through its antioxidant properties (Boroumand et al., 2018). In feed, Turmeric can remove free radicals without Vitamin E (Boroumand et al., 2018). Turmeric possesses anti-inflammatory properties. If Vitamin C is absent in feed, there will be a slow healing process (Boroumand et al., 2018). However, using turmeric in the feed will compensate for Vitamin C deficiency, and no compromise will be made in the healing process. Turmeric possesses an immunomodulatory effect. Suppose it is used in birds' diet. In that case, there will be proper development of immune organs and early production and maturation of immune cells such as B lymphocytes, T lymphocytes, cytokines, etc. Turmeric can compensate for the deficiencies of vitamins and amino acids like arginine, which are essential for thymus weight and function (Alcala et al., 2023). It can be used in a powder form in poultry feed at specific concentrations.

Table 1: Composition of diets containing turmeric powder for starter (0-21 days) and grower period (21-42 days)

Ingredients	Starter diet 0.4% TP	Starter diet 0.8% TP	Grower diet 0.4% TP	Grower diet 0.8% TP
Corn	61.35	61.30	69.12	68.95
Soybean	30.80	30.00	22.63	21.54
Gluten meal	3.50	4.00	4.05	4.90
Turmeric powder	0.40	0.80	0.40	0.80
Oyster shell	1.48	1.45	1.38	1.38
Dicalcium phosphate	1.40	1.36	1.25	1.25
Salt	0.40	0.40	0.35	0.35
Vita. Premix	0.25	0.25	0.25	0.25
Min. premix	0.25	0.25	0.25	0.25
DL-methionine	0.13	0.13	0.13	0.14
L-lysine	0.04	0.05	0.19	0.20
Nutrient composition				
Metabolizable energy (kcal/kg)	2933	2932	3020	3020
Crude protein %	21.51	21.49	18.97	18.97
Lysine %	1.15	1.15	1.03	1.03
Met + Cys %	0.88	0.88	0.82	0.83
Calcium	0.95	0.96	0.89	0.89
Available phosphorous %	0.44	0.44	0.42	0.41

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Besides antimicrobial, antioxidant, anti-inflammatory, and immunomodulatory effects (Alcala et al., 2023), turmeric has the most significant role in the poultry industry in terms of better growth performance, good feed conversion ratio, better immune system, respiratory system, and digestive system development (Ekine et al., 2020). There is research available on the use of turmeric in birds regarding growth performance (Qasem et al., 2015). One study has shown that if turmeric is used in 0.4% of the feed, then at 28 days, body weight will be 1053 g/bird by consuming 1604 g/bird feed, giving 1.523 FCR (Khodadadi et al., 2021). Another research has shown that if turmeric is used in 0.8% of the feed, then at 28 days, body weight will be 1062 g/bird by consuming 1566 g/bird feed, giving 1.473 FCR (Kichu et al., 2023). We can use turmeric in feed at 0.8% and 0.4% concentrations because the bird has good growth performance at both levels.

Factors related to Infectious agents

Protozoa

Within protozoa, coccidia is related to immunosuppression. Cryptosporidium baileyi and Eimeria are related to immunosuppression in birds. Only mitogen stimulation responses are affected later with the infection (McDougald et al., 2019), but there is no change in antibody responses to the T cell-dependent and independent antigens. C. Baileyi is more prevalent than diagnostic cases because it replicates in chicken's bursal epithelial cells and respiratory tract (Schat & Skinner, 2022). Oral transmission in young chickens with C. Baileyi results in lesions in the epithelium and lamina propria of the bursa (Abbassi, Dambrine, et al., 2000), as well as a decrease in antibody responses to the T cell-dependent and T cell-independent antigens. Titers of various vaccines such as IBV, NDV, and AI vaccine also decrease due to oral transmission (Rhee et al., 1998). However, it has been found that C. Baileyi infection is not related to the increase in Marek's disease or the decrease in efficacy of the MDV vaccine strain CVI988 (Abbassi, Coudert, et al., 2000).

Fungi

The presence of fungal toxins and mycotoxins in feed can cause immunosuppression in chickens. The importance of mycotoxins and immunosuppressive toxins and their effects have been studied (Bondy & Pestka, 2000b). The best-known fungal toxin is Aflatoxin B1 for poultry, but chickens are resistant, with more toxic effects for ducks and turkeys (Yunus et al., 2011b). After ingestion of Aflatoxin B1, there is cytotoxicity through a specific mechanism as it is hydrolyzed in live by cytochrome P450 into aflatoxin-8,9-epoxide, a highly toxic component, which can bind to DNA or proteins. This results in cell death in primary lymphoid organs and decreased performance, especially in broilers. During initial exposure, antibody responses may increase at low levels (Yunus et al., 2011b), but antibody and CMI responses generally fall. It has been studied that chicks fed on aflatoxin-containing diets after hatching showed abnormal immune functions, but it is not known how long this effect will last (Qureshi et al., 1998b).

Fumonisins, ochratoxins, and trichothecenes have immunotoxic effects in ducks, turkeys, and chickens. It has been studied that there is a reduction in macrophage activity, secondary antibody responses to ND vaccines, and gene expression of interleukins and interferons if low levels of fumonisin B1 (15ppm) are fed to broilers in feed. However, this level is acceptable in chicken feed because it does not reduce growth performance (Cheng et al., 2006b). T-2 and DON, two toxins of the trichothecenes group, have immunomodulation effects in chickens (Rezar et al., 2007b). High doses of T-2 and DON can cause immunosuppression, but low doses can cause an increase in IgA levels and titers against NDV. IBDV-affected broilers have more severe effects when fed with a containing diet than those fed with a diet lacking in DON (Cheng et al., 2006b). A complex relationship exists between immune responses and trichothecenes (Pestka et al., 2004b). High doses result in apoptosis due to the activation of caspases, but low doses stimulate immune responses due to cytokines and chemokines. OTAs are highly toxic and can be found in eggs if fed in feed. These cause decreased innate and acquired immune responses and increased susceptibility to disease in chickens fed OTA $1ppm and their progeny (Hassan et al., n.d.). For example, at 2ppm concentration, OTA causes an increase in mortality in chickens affected with Salmonella enteric subspecies enterica serovar Gallinarum. More than one mycotoxins are present in feed, and their interactions increase the immunosuppressive effects (Tessari et al., 2006).

Virus:

Infectious Bursal Disease (IBD)

A highly contagious and acute viral disease that affects young chickens and turkeys is the Infectious Bursal Disease virus (IBDV), which causes severe damage to the bursa of Fabricius, which plays a vital role in immune system development (Mahgoub, 2012). This virus causes immunosuppression in birds, infecting and destroying plasma cells present in bursa from which there is production of B-lymphocytes responsible for antibody production (Liu & Vakharia, 2006). IBDV affects the host in two ways: the respiratory and digestive systems (Wei et al., 2011). After that, its replication occurs in intestinal epithelial cells and invades bursal lymphocytes. The destruction of bursal lymphocytes results in a decrease in B-lymphocyte production; thus, a reduction in the production of antibodies leads to a decline in the level of circulating antibodies, and the bird is susceptible to other infections (Yao & Vakharia, 2001). IBDV possesses the property to inhibit lymphocyte proliferation, resulting in a decrease in lymphocyte production. This effect is due to VP2 and VP5 viral proteins, which inhibit the activation of NK-kB transcription factors essential for lymphocyte proliferation (Rodríguez-Lecompte et al., 2005). IBDV is linked with immunosuppression by inhibiting the production of cytokines such as IL-1 and IL-6. This effect is due to VP4 viral protein. IBDV impairs the antigen presentation process required to activate the immune response. This effect t is due to the VP2 viral protein, which can inhibit the expression of the major histocompatibility complex (MHC) class I molecules (Rodenberg et al., 1994).

Chicken Infectious Anaemia (CIA):

A small, non-enveloped, single-stranded DNA virus that infects young chickens of less than three weeks of age is the Chicken Infectious Anaemia Virus (CIAV) (Alkateb & Gerish, 2019). The bone marrow responsible for immune cell production, such as white blood cells, is infected and damaged by CIAV, resulting in decreased immune function due to decreased circulating lymphocytes in the blood (Schat & Van Santen, 2019). CIAV infects and damages the thymus and spleen, where immune cell maturation and activation occur, resulting in reduced production and activation of immune cells (Gimeno & Schat, 2018). CIAV suppresses cytokine production, necessary for coordinating immune responses, and decreases interferon-alpha production, essential for an antiviral immune response (Matta et al., 2017). CIAV also infects the macrophage's function by minimizing the phagocytic activity of macrophages, compromising the bird's immune system (Ramzy et al., 2023).

Avian Leukosis and Reticuloendotheliosis:

Retroviruses are related to several diseases in humans and animals, such as leukemia, acquired immunodeficiency syndrome, and neurodegenerative diseases (Nakamura et al., 2014). Avian leukosis and reticuloendotheliosis are common in chickens, turkeys, and other avian species and cause different types of effects like tumors, immunosuppression, and reduced productivity (Payne & Nair, 2012). Runting syndrome and bursal atrophy have been shown in chickens due to replication-competent REV strain A and chicken syncytial virus (Payne & Nair, 2012). Chicken infected with REV has to face immunosuppression, which results in acute leukemia by inhibiting cytotoxic cell proliferation against tumor cell antigens (Nakamura et al., 2014). Chickens infected with REV and having NDV as co-infection show more severe clinical signs with reduced antibody responses (Nakamura et al., 2014; Payne & Nair, 2012). Immunosuppression is caused by the myeloblastosis strain of avian leukosis virus that induces osteopetrosis, due to which there is an occurrence of lymphoid organs atrophy and decreased macrophage function and bacterial clearance as well as thymus atrophy and reduced T-cell competencies (Nakamura et al., 2014) occur due to erythroblastosis strain of ALV (Payne & Nair, 2012). It has been eradicated in some countries from primary broiler breeder flocks through rigorous application of well-tested eradication programs, but in other countries, it is present in layers flocks. Due to viral mutation, a new threat is expected to the poultry industry.

Table 2: Agents responsible for atrophy of some immune organs.

Agent	Bursa of Fabricius	Thymus	GALT
Infectious bursal disease	Yes	Yes	Yes
Chicken infectious anemia	Yes	Yes	Yes
Marek's disease	Yes	Yes	Yes
Reovirus	Yes	Yes	Yes
Reticuloendotheliosis virus	Yes	Yes	Yes
Newcastle disease virus	Yes	No	Yes
Mycoplasma	Yes	Yes	Yes
Ammonia	Yes	No	Yes
Mycotoxin	Yes	Yes	Yes
Heat stress	No	Yes	Yes

Role of Turmeric in infectious agents:

Antimicrobial

Turmeric contains a bioactive compound called curcumin, which possesses antimicrobial properties (Abd El-Hack et al., 2021). This effect is due to the ability of curcumin to inhibit various microorganisms' growth and proliferation of microorganism through the disruption of cell membrane integrity, inhibition of enzymes, and inhibition of gene expression (Zheng et al., 2020). Curcumin interacts with and damages the cell membrane of microorganisms, resulting in a leakage of intracellular contents, ultimately leading to cell death (Tyagi et al., 2015). It involves and stops the pathogenesis of bacterial infections by inhibiting bacterial enzyme activity, such as metalloprotease and beta-lactamases. It reduces the virulency and pathogenicity of the microorganisms by interfering with the expressions of virulence factors and biofilm formation genes involved in microbial pathogenesis (Vairagar et al., 2023). Curcumin promotes the phagocytosis of microorganisms by modulating the host immune system by stimulating the production of cytokines and chemokines, which enhance macrophage and neutrophil activity (Mohammadi et al., 2019).

Anti-inflammatory

Several studies regarding turmeric's anti-inflammatory properties demonstrated both in vitro and in vivo (Vairagar et al., 2023). Its anti-inflammatory effect is explained in several ways, like inhibiting inflammatory cytokines, inhibiting inflammatory enzymes, and modulation of transcription factors (Yahfoufi et al., 2018). It inhibits the production of pro-inflammatory cytokines by macrophages such as tumor necrosis factor-alpha, interleukin-1 beta, and interleukin-6. It inhibits the function of cyclooxygenase-2, and lipoxygenase inflammatory enzymes have a role in producing prostaglandins and leukotrienes, which are inflammatory mediators (Azeez & Lunghar, 2021). Curcumin modulates the nuclear kappa B transcription factor, which regulates inflammation-promoting genes. Preclinical and clinical studies show curcumin's anti-inflammatory properties (Azeez & Lunghar, 2021). It reduces inflammation in psoriasis, inflammatory bowel disease, osteoarthritis, and rheumatoid arthritis. It targets multiple inflammatory pathways, making it the best therapeutic option for chronic inflammatory conditions (Kunnumakkara et al., 2017).

Antioxidant:

Along with other properties, curcumin also possesses antioxidant properties in various organisms, including birds (Lee et al., 2017). Its antioxidant properties in birds are similar to those in other animals through different mechanisms like scavenging free radicals (Lee et al., 2017), upregulation of antioxidant enzymes, modulation of

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signaling pathways, and chelation of transition metals (Ge et al., 2021). Curcumin possesses the property of a free radical scavenger as it neutralizes reactive oxygen species (ROS) and other free radicals responsible for cellular damage. When birds are exposed to different conditions like environmental pollutants, infections, or normal metabolic processes, ROS are produced, but this property of curcumin to scavenge free radicals protects the bird's cells from oxidative damage (Abo-Al-Ela et al., 2021). Curcumin upregulates the functions of superoxide dismutase, catalase, and glutathione peroxidase antioxidant enzymes to protect bird cells from oxidative damage (Ruan et al., 2019). In birds, various diseases emerge due to oxidative stress, such as cancer and neurodegenerative diseases. However, the use of curcumin in poultry feed can overcome these diseases. It modulates the signaling pathways involved in oxidative stress, like the nuclear factor erythroid 2-related factor 2 (Nrf2) pathway, which regulates the antioxidant gene expression. Modulating this pathway improves the antioxidant defense system. Curcumin possesses the property to chelate metals like iron and copper, which are responsible for the catalyzation of the production of ROS and oxidative stress (Ruan et al., 2019). Curcumin protects birds from metal-induced toxicity. Curcumin's antioxidant properties have been studied in chicken, quail, and pigeons. It improves antioxidant enzyme activity to reduce lipid peroxidation (Eleiwa et al., 2023).

Conclusion

A robust immune system is vital to keep poultry birds healthy. Immunosuppression can be due to non-infectious agents such as environmental stressors and nutritional deficiencies and can be due to infectious agents such as protozoa, fungi, viruses, and bacteria. These infectious agents cause different bird diseases like coccidiosis, aspergillosis, aflatoxicosis, infectious bursal diseases (IBD), chicken infectious anemia (CIA), avian leukosis, and reticuloendotheliosis. These diseases primarily affect immune organs, suppressing the bird's immunity and increasing susceptibility to other infections. In these conditions, different supportive therapies and antibiotics are given to birds to minimize the chances of secondary bacterial infections. However, excessive use of antibiotics is prohibited. So, using natural herbs like turmeric with the same properties as antibiotics is better. This will reduce the use of antibiotics and public health issues as well.

Declarations

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All data generated or analyzed during the study are included in the manuscript.
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TARIQ JAMIL
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Manuscript revisions, critical input.

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