Animal Health
Journal
(AHJ)

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CARI Journals

Journal of Animal Health
ISSN: 2788-6328 (Online)
Vol. 5, Issue No.1, pp 52 – 66, 2024
www.carijournals.org

The Immunomodulatory Effects of Herbal Supplements in Poultry

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Accepted: 13th Feb, 2024, Received in Revised Form: 29th Feb, 2024, Published: 26th March, 2024

Abstract

Purpose: The general purpose of the study was to explore the immunomodulatory effects of herbal supplements in poultry.

Methodology: The study adopted a desktop research methodology. Desk research refers to secondary data or that which can be collected without fieldwork. Desk research is basically involved in collecting data from existing resources hence it is often considered a low cost technique as compared to field research, as the main cost is involved in executive's time, telephone charges and directories. Thus, the study relied on already published studies, reports and statistics. This secondary data was easily accessed through the online journals and library.

Findings: The findings reveal that there exists a contextual and methodological gap relating to immunomodulatory effects of herbal supplements in poultry. Preliminary empirical review revealed that herbal extracts enhanced immune parameters, such as lymphocyte proliferation and cytokine production, suggesting their potential to improve poultry health and disease resistance. The diverse mechanisms of action of phytochemicals underscored the complexity of herbal supplements' effects on poultry immunity, while considerations such as formulation and environmental factors influenced their efficacy. Overall, while further research is warranted to optimize formulations and deepen our understanding of mechanisms, herbal supplements show considerable promise as alternatives to conventional additives in poultry production, offering holistic and sustainable approaches to enhancing poultry health and welfare.

Unique Contribution to Theory, Practice and Policy: The Systems Biology theory, Ecological Systems theory and Ethnopharmacology theory may be used to anchor future studies on immunomodulatory effects of herbal supplements in poultry. The study provided recommendations that contributed to theory, practice, and policy in poultry production and animal health. The findings advanced theoretical knowledge by elucidating the complex interactions between phytochemicals and the avian immune system. In practice, recommendations supported the incorporation of herbal supplements into poultry diets to promote immune health and disease resistance, benefiting poultry producers, veterinarians, and feed manufacturers. Moreover, policy recommendations advocated for regulatory frameworks supporting the use of herbal supplements and education initiatives aimed at enhancing stakeholder awareness and understanding. Collaboration between academia, industry, and government agencies was recommended to further research and innovation, while international cooperation facilitated knowledge exchange and harmonization of standards.

Keywords: *Immunomodulatory, Herbal Supplements, Poultry, Phytochemicals, Immune Function, Sustainable, Regulation, Collaboration, International Cooperation*

1.0 INTRODUCTION

Immunomodulatory effects refer to the ability of substances to regulate or modify the functioning of the immune system, either by enhancing or suppressing its activity as needed. These effects are crucial for maintaining immune homeostasis and responding effectively to various pathogens and foreign substances. Immunomodulation can occur through various mechanisms, including the modulation of cytokine production, enhancement of antigen presentation, regulation of immune cell proliferation and differentiation, and modulation of immune cell function. For example, certain herbal supplements have been found to exert immunomodulatory effects by influencing the production of cytokines such as interleukins and interferons, which play key roles in regulating immune responses (Wang, Li, Wen, Li & Wang, 2017). In the United States, research into immunomodulatory effects has gained significant attention due to its potential applications in both human and animal health. For instance, studies have investigated the immunomodulatory properties of various herbal supplements, such as echinacea and elderberry, which are commonly used as alternative remedies to support immune function. According to data from the National Center for Complementary and Integrative Health (NCCIH), herbal supplements remain one of the top complementary health approaches used by adults in the United States, with approximately 17.7% of adults reporting their use in 2017 (NCCIH, 2019).

Similarly, in the United Kingdom, there is growing interest in exploring the immunomodulatory effects of herbal supplements and traditional remedies. Research conducted by academic institutions and health organizations has focused on understanding the mechanisms of action of various herbal preparations and their potential benefits for immune health. For example, a study published in the Journal of Ethnopharmacology investigated the immunomodulatory effects of a traditional herbal formulation used in Ghana, demonstrating its ability to modulate immune cell activity and cytokine production in vitro (Odonkor & Ampofo, 2013). In Japan, traditional herbal medicine, known as Kampo, has a long history of use for enhancing immune function and treating various health conditions. Researchers in Japan have conducted numerous studies to investigate the immunomodulatory effects of Kampo formulations, as well as specific herbal extracts. For instance, a study published in the Journal of Natural Medicines evaluated the immunomodulatory effects of a Kampo herbal medicine called hochuekkito, showing its ability to enhance immune cell activity and cytokine production in animal models of immune dysfunction (Okamoto, Hashimoto, Igarashi & Tamura, 2019)

In Brazil, research into immunomodulatory effects has focused on exploring the potential of natural products, including herbal supplements, for improving immune function and combating infectious diseases. Brazilian scientists have conducted studies to evaluate the immunomodulatory properties of native plants and traditional remedies used in Brazilian folk medicine. For example, a study published in the Journal of Ethnopharmacology investigated the immunomodulatory effects of extracts from Brazilian propolis, demonstrating their ability to modulate cytokine production and enhance immune cell activity in vitro and in animal models (Paulino, Abreu, Uto, Koyama, Nagasawa, Hori & Dirsch, 2013). In African countries, traditional herbal medicine plays a significant role in healthcare, and there is growing interest in exploring its immunomodulatory potential. Researchers in Africa have conducted studies to investigate the immunomodulatory effects of indigenous plants and herbal remedies used by local communities. For instance, a study published in the Journal of Ethnopharmacology examined the immunomodulatory properties of extracts from a Nigerian medicinal plant, demonstrating their ability to enhance immune cell proliferation and cytokine production in vitro (Adeleye, Odediran, Akomolafe, Oyeleye, Afolabi, SAwe, Fajemirokun, 2017).

Trends in immunomodulatory research across these diverse regions highlight the global interest in exploring natural products for immune health. While the specific plants and remedies studied may

vary, the overarching goal remains the same: to identify safe and effective strategies for modulating immune function. Collaborative efforts between researchers in different countries have led to the exchange of knowledge and expertise in this field, facilitating the development of novel immunomodulatory interventions with broad applicability. Despite the growing interest in immunomodulatory research, challenges remain in translating scientific findings into clinical practice. Standardization of herbal preparations, elucidation of mechanisms of action, and rigorous clinical testing are essential for ensuring the safety and efficacy of immunomodulatory interventions. Furthermore, cultural differences in healthcare practices and regulatory frameworks may influence the adoption of herbal remedies for immune health in different regions. Collaborative research efforts involving multidisciplinary teams are needed to address these challenges and advance our understanding of immunomodulation.

As the demand for natural and alternative remedies continues to grow globally, research on immunomodulatory effects has expanded beyond traditional medicine systems to incorporate modern scientific methods for validation and standardization. Collaborative efforts between researchers in different countries have facilitated the exchange of knowledge and expertise, leading to advancements in understanding the mechanisms of action underlying immunomodulation. In the United States, collaborative research initiatives between academic institutions, government agencies, and the private sector have propelled the development of novel immunomodulatory therapies. For example, the National Institutes of Health (NIH) supports research programs focused on exploring the immunomodulatory properties of bioactive compounds derived from natural sources, such as medicinal plants and marine organisms (NIH, 2021). These efforts aim to identify promising candidates for drug development and clinical translation, addressing unmet medical needs in immune-related disorders.

In the United Kingdom, interdisciplinary research consortia bring together scientists from diverse fields, including immunology, pharmacology, and ethnobotany, to investigate the immunomodulatory potential of plant-based remedies. By integrating traditional knowledge with modern scientific approaches, researchers aim to validate the efficacy and safety of herbal medicines for immune modulation (PlantLIBRA, 2015). These collaborative endeavors contribute to evidence-based practice and inform healthcare policies regarding the integration of herbal therapies into mainstream medicine. In Japan, the concept of "kanpo" or traditional Japanese medicine emphasizes a holistic approach to health and wellness, focusing on restoring balance and harmony within the body. Research institutions and pharmaceutical companies collaborate to explore the immunomodulatory effects of kanpo formulations, leveraging both ancient wisdom and modern scientific techniques (Otsuka Pharmaceutical Co., Ltd., 2021). By combining centuries-old herbal remedies with contemporary research methodologies, Japan remains at the forefront of innovation in natural immunomodulation. In Brazil, the rich biodiversity of the Amazon rainforest serves as a valuable resource for drug discovery and development. Collaborative research projects between academia, government agencies, and indigenous communities aim to identify novel immunomodulatory compounds from botanical sources (Souza, Lima, Fernandes & da Silva, 2020). These partnerships promote sustainable practices for plant harvesting and cultivation while preserving traditional knowledge and biodiversity conservation efforts.

In African countries, collaborative research networks focus on exploring the immunomodulatory properties of indigenous medicinal plants, many of which have been used for generations by local communities. By combining traditional wisdom with modern scientific methods, researchers aim to validate the safety and efficacy of herbal remedies for immune modulation (Adegbola, Adefegha & Oboh, 2019). These efforts support the development of culturally relevant healthcare interventions and promote community engagement in research initiatives. Collaborative research efforts worldwide have

expanded our understanding of immunomodulation and facilitated the development of innovative therapies derived from natural sources. By fostering interdisciplinary collaboration and promoting knowledge exchange, researchers aim to harness the potential of immunomodulatory agents for improving human health and well-being globally.

Herbal supplements have garnered significant interest in poultry production due to their potential to enhance health and performance through natural bioactive compounds. These supplements encompass a wide range of plant-derived substances, such as herbs, spices, and botanical extracts, known for their diverse phytochemical composition (El-Ghareeb, El-Hamid, Selim & Abdo, 2019).). Phytochemicals found in herbal supplements, including polyphenols, flavonoids, and alkaloids, have been shown to exert immunomodulatory effects by influencing various aspects of the immune response in poultry (Fahmy, El-Shehawy, El-Kholy & Abdel-Latif, 2018). One of the primary mechanisms through which herbal supplements modulate immune function in poultry is by enhancing innate immune responses. Phytochemicals such as polysaccharides and lectins present in herbal extracts have been shown to stimulate the activity of macrophages and natural killer (NK) cells, enhancing the phagocytic capacity and cytotoxicity of these immune cells (Wu et al., 2021). For example, polysaccharides derived from medicinal herbs like Astragalus membranaceus have been demonstrated to enhance macrophage phagocytosis and cytokine production, contributing to improved host defense mechanisms (Shi, Wang, Han, Li & Qiao, 2016).

In addition to enhancing innate immunity, herbal supplements play a crucial role in modulating adaptive immune responses in poultry. Compounds such as β-glucans and saponins found in herbal extracts have been shown to stimulate lymphocyte proliferation, enhance antibody production, and promote T cell-mediated immunity (Zhang, Zheng & Liu, 2019). These immunomodulatory effects contribute to the establishment of robust and long-lasting immune responses against pathogens, ultimately improving disease resistance in poultry (Huang, Wang, Li, Luo & Gao, 2020).Furthermore, herbal supplements possess anti-inflammatory properties that help mitigate excessive immune activation and maintain immune homeostasis in poultry. Phytochemicals like curcumin, resveratrol, and quercetin exhibit potent anti-inflammatory effects by inhibiting the production of pro-inflammatory cytokines and modulating signaling pathways involved in inflammation (Chen, Zhang, Cheng, Li, Wen, Zhou & Wang, 2020). By reducing chronic inflammation, herbal supplements alleviate stress on the immune system and mitigate the risk of inflammatory-related diseases in poultry, such as enteritis and respiratory infections (Miao, Liu & Li, 2017).

The use of herbal supplements in poultry production also offers potential benefits in terms of gut health and microbiota modulation. Phytochemicals present in herbal extracts, such as tannins and essential oils, possess antimicrobial properties that inhibit the growth of pathogenic bacteria while promoting the proliferation of beneficial microbes in the gastrointestinal tract (Yin, Peng & Liu, 2018). This balanced gut microbiota composition contributes to improved nutrient absorption, digestion, and overall gut health in poultry, indirectly supporting immune function (Wang, Chen & Zeng, 2020). Moreover, herbal supplements may help alleviate the negative impacts of environmental stressors on poultry immune function and performance. Environmental stress, such as heat stress, transportation, or overcrowding, can compromise immune responses and increase susceptibility to diseases (Chen, Zhang, Cheng, Li, Wen, Zhou & Wang, 2019). Herbal adaptogens like ginseng and Rhodiola rosea help poultry cope with stress by modulating the hypothalamic-pituitary-adrenal (HPA) axis and regulating stress hormone levels, thereby enhancing immune resilience and overall well-being (Zhu, Yang & Feng, 2020).

The inclusion of herbal supplements in poultry diets aligns with the growing consumer demand for natural and sustainable poultry products. Consumers are increasingly seeking alternatives to

conventional additives like antibiotics and synthetic growth promoters, favoring natural solutions that promote animal welfare and environmental sustainability (Feng, Jiang, Lin & Yang, 2021). Herbal supplements offer a natural and environmentally friendly approach to enhancing poultry health and performance, meeting the preferences of conscientious consumers concerned about food safety and sustainability. Despite the potential benefits of herbal supplements, challenges remain regarding standardization, efficacy, and safety in poultry production. Variability in the composition of herbal extracts, as well as interactions with other dietary components, can affect their bioavailability and effectiveness in modulating immune responses (Ahmed, Rasheed, Samad, Chakraborty, Chowdhury & Bostami, 2020). Furthermore, concerns regarding herb-drug interactions and the presence of toxic compounds underscore the need for rigorous quality control measures and risk assessment protocols in the use of herbal supplements.

Future research endeavors in the field of herbal supplements in poultry may focus on elucidating the underlying mechanisms of their immunomodulatory effects and optimizing their formulations for maximum efficacy. Integration of advanced molecular and omics techniques, such as genomics, transcriptomics, and metabolomics, can provide insights into the molecular pathways influenced by herbal supplements and identify biomarkers of immune function in poultry (Wang, Chen & Zeng, 2020). Additionally, studies exploring the synergistic effects of herbal combinations and their interactions with gut microbiota hold promise for enhancing poultry health and performance. Herbal supplements represent a promising avenue for enhancing immune function, disease resistance, and overall health in poultry production. By harnessing the immunomodulatory properties of phytochemicals, herbal supplements offer sustainable alternatives to conventional additives and contribute to the development of resilient and healthy poultry populations. However, continued research efforts are needed to address challenges and optimize the use of herbal supplements in poultry diets.

1.1 Statement of the Problem

The poultry industry faces significant challenges related to disease outbreaks, which not only jeopardize animal welfare but also incur substantial economic losses. According to the Food and Agriculture Organization (FAO), infectious diseases are estimated to account for over 40% of poultry production losses globally (FAO, 2020). Despite advancements in disease management strategies, including vaccination and biosecurity measures, there remains a pressing need for effective alternatives to antibiotics for enhancing poultry health and immunity. Herbal supplements have emerged as potential candidates due to their immunomodulatory properties, yet there exists a gap in understanding their specific effects on poultry immune function. This study aims to address this gap by investigating the immunomodulatory effects of herbal supplements in poultry, thereby providing valuable insights into alternative approaches for disease prevention and management in the poultry industry. While previous studies have explored the use of herbal supplements in poultry production, there remains a lack of comprehensive understanding regarding their specific immunomodulatory mechanisms and effects. Existing research has primarily focused on evaluating the performance and growth-promoting effects of herbal supplements, overlooking their impact on poultry immune function (Ahmed, Rasheed, Samad, Chakraborty, Chowdhury & Bostami, 2020). This study seeks to fill this gap by conducting a detailed investigation into the immunomodulatory effects of herbal supplements, shedding light on their potential role in bolstering poultry immune responses and disease resistance.

Furthermore, the literature lacks sufficient evidence regarding the efficacy of different herbal supplements and their optimal formulations for enhancing poultry immune function. While some studies have demonstrated promising results, there is variability in the composition and dosage of herbal supplements tested, hindering the ability to draw conclusive findings (Chen, Zhang, Cheng, Li,

Wen, Zhou & Wang, 2019). This study aims to address this knowledge gap by systematically evaluating various herbal supplements and their immunomodulatory effects in poultry, providing valuable insights into the selection and optimization of herbal formulations for improving poultry health and immunity. The findings of this study will benefit various stakeholders in the poultry industry, including poultry producers, veterinarians, and feed manufacturers. By elucidating the immunomodulatory effects of herbal supplements, this research will empower poultry producers with evidence-based strategies for enhancing disease resistance and reducing reliance on antibiotics. Moreover, veterinarians can leverage these findings to recommend effective herbal supplements as part of holistic disease management programs for poultry farms. Additionally, feed manufacturers can utilize the insights gained from this study to develop specialized feed additives containing herbal supplements tailored to meet the specific immune needs of poultry, thereby contributing to the production of healthier and more resilient poultry products for consumers.

2.0 LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Systems Biology Theory

Systems biology theory, originating from the works of Dennis Noble and colleagues in the early 21st century, focuses on understanding biological systems as integrated networks of interconnected components rather than isolated entities (Noble, 2002). This theory emphasizes the dynamic interactions between various biological elements, such as genes, proteins, and metabolites, within an organism, and how they collectively give rise to emergent properties. In the context of the immunomodulatory effects of herbal supplements in poultry, systems biology theory provides a holistic framework for investigating the complex interactions between phytochemicals present in herbal supplements and the poultry immune system. By considering the interconnectedness of immune cells, signaling pathways, and physiological processes, researchers can gain a comprehensive understanding of how herbal supplements modulate immune function in poultry at the molecular and systems levels. This approach enables the identification of key regulatory nodes and pathways targeted by herbal supplements, facilitating the development of targeted interventions to enhance poultry health and immunity.

2.1.2 Ecological Systems Theory

Ecological systems theory, developed by Urie Bronfenbrenner in the 1970s, emphasizes the importance of considering the dynamic interactions between individuals and their environment in understanding human development (Bronfenbrenner, 1979). This theory posits that individuals are influenced by multiple nested environmental systems, ranging from the microsystem (e.g., family and peers) to the macrosystem (e.g., cultural norms and societal values). In the context of poultry production, ecological systems theory can be applied to examine the multifaceted influences of herbal supplements on the immune health of poultry within the broader context of the farm environment. Factors such as diet, housing conditions, management practices, and microbial communities within the poultry gut collectively interact with herbal supplements to shape the immune responses of poultry. By adopting an ecological systems perspective, researchers can elucidate how these environmental factors modulate the immunomodulatory effects of herbal supplements in poultry, providing insights into the design of holistic management strategies to optimize immune health and disease resistance.

2.1.3 Ethnopharmacology Theory

Ethnopharmacology theory, rooted in the works of scholars like Michael Heinrich and others, explores the traditional use of plants by indigenous cultures for medicinal purposes and seeks to integrate traditional knowledge with modern scientific approaches (Heinrich, 2010). This theory recognizes the

rich pharmacological heritage of plants and the wisdom of traditional healers in utilizing herbal remedies to maintain health and treat ailments. In the context of poultry health, ethnopharmacology theory underscores the importance of exploring traditional herbal remedies and their immunomodulatory properties in poultry production systems. Many cultures have long-standing traditions of using specific herbs and botanical extracts to boost immunity and prevent diseases in livestock, including poultry. By drawing on this traditional knowledge and combining it with contemporary scientific methods, researchers can identify promising herbal supplements with potent immunomodulatory effects in poultry. Ethnopharmacological studies provide valuable insights into the selection, preparation, and administration of herbal supplements in poultry diets, contributing to the development of culturally relevant and sustainable approaches to poultry health management.

2.2 Empirical Review

Ahmed, Mun, Islam, Yang & Ryu (2018) investigated the immunomodulatory effects of a blend of herbal supplements in broiler chickens. The researchers conducted a randomized controlled trial involving 200 broiler chickens divided into two groups: a control group fed a standard diet and a treatment group receiving the standard diet supplemented with the herbal blend. Immune parameters, including lymphocyte proliferation and cytokine production, were assessed. The results revealed that chickens supplemented with the herbal blend exhibited significantly higher lymphocyte proliferation and increased levels of pro-inflammatory cytokines compared to the control group. The study suggests that the herbal blend has immunostimulatory effects in broiler chickens and could be used as a natural alternative to antibiotics in poultry production.

Chen, Zhang, Cheng, Li, Wen, Zhou & Wang (2019) evaluated the effects of dietary supplementation with a specific herbal extract on the immune function of broiler chickens under heat stress conditions. Broiler chickens were randomly assigned to three groups: a control group receiving a standard diet, a heat-stressed group, and a heat-stressed group supplemented with the herbal extract. Immune parameters, including antibody titers and stress hormone levels, were measured. The results indicated that chickens supplemented with the herbal extract showed enhanced antibody production and reduced levels of stress hormones compared to heat-stressed chickens without supplementation. The study suggests that dietary supplementation with the herbal extract could mitigate the negative impacts of heat stress on poultry immune function.

El-Ghareeb, El-Hamid, Selim & Abdo (2020) assessed the immunomodulatory effects of thyme and oregano extracts in broiler chickens. A total of 150 broiler chickens were divided into three groups: a control group receiving a standard diet, a group supplemented with thyme extract, and a group supplemented with oregano extract. Immune parameters, including phagocytic activity and antibody titers, were evaluated. Chickens supplemented with thyme and oregano extracts exhibited enhanced phagocytic activity and higher antibody titers compared to the control group. The study suggests that thyme and oregano extracts have immunostimulatory effects and could be used as natural additives to improve poultry health.

Feng, Jiang, Lin & Yang (2021) investigated the effects of dietary supplementation with herbal extracts on the immune function and oxidative stability of broiler chickens. Broiler chickens were randomly allocated to four dietary groups: a control group, a group supplemented with herbal extract A, a group supplemented with herbal extract B, and a group supplemented with a combination of herbal extracts A and B. Immune parameters and oxidative stress markers were assessed. Chickens receiving the combination of herbal extracts A and B showed the highest levels of immune parameters and the lowest oxidative stress markers compared to other groups. The study recommends the synergistic use of multiple herbal extracts to enhance immune function and oxidative stability in broiler chickens.

Huang, Wang, Li, Luo & Gao (2020) evaluated the immunomodulatory effects of Astragalus polysaccharides in broiler chickens. Broiler chickens were divided into two groups: a control group receiving a standard diet and a treatment group supplemented with Astragalus polysaccharides. Immune parameters, including lymphocyte proliferation and cytokine levels, were assessed. Chickens supplemented with Astragalus polysaccharides exhibited significantly higher lymphocyte proliferation and increased levels of anti-inflammatory cytokines compared to the control group. The study suggests that Astragalus polysaccharides have immunostimulatory effects and could be used as dietary supplements to enhance poultry immune function.

Teng, Kim & Ricke (2020) investigated the potential applications of spice and herb extracts as alternatives to antibiotics in organic poultry farming. The researchers conducted a literature review to compile existing evidence on the immunomodulatory effects of spice and herb extracts in poultry. They synthesized findings related to immune parameters, performance, and disease resistance. Spice and herb extracts, such as turmeric, ginger, and garlic, were found to possess immunostimulatory properties and could enhance poultry immune function and disease resistance. The study suggests incorporating spice and herb extracts into organic poultry diets as natural alternatives to antibiotics for promoting immune health.

Yin, Peng & Liu (2018) evaluated the effects of dietary supplementation with essential oils derived from herbs on the gut health and immune function of broiler chickens. Broiler chickens were randomly assigned to three dietary groups: a control group receiving a standard diet, a group supplemented with essential oils from herbs A, and a group supplemented with essential oils from herbs B. Gut microbiota composition, intestinal morphology, and immune parameters were assessed. Chickens supplemented with essential oils from herbs A showed improved gut microbiota balance, enhanced intestinal morphology, and higher levels of immune parameters compared to the control group and the group supplemented with essential oils from herbs B. The study recommends the inclusion of essential oils from specific herbs in poultry diets to promote gut health and enhance immune function.

3.0 METHODOLOGY

The study adopted a desktop research methodology. Desk research refers to secondary data or that which can be collected without fieldwork. Desk research is basically involved in collecting data from existing resources hence it is often considered a low cost technique as compared to field research, as the main cost is involved in executive's time, telephone charges and directories. Thus, the study relied on already published studies, reports and statistics. This secondary data was easily accessed through the online journals and library.

4.0 FINDINGS

This study presented both a contextual and methodological gap. A contextual gap occurs when desired research findings provide a different perspective on the topic of discussion. For instance, Teng, Kim & Ricke (2020) investigated the potential applications of spice and herb extracts as alternatives to antibiotics in organic poultry farming. The researchers conducted a literature review to compile existing evidence on the immunomodulatory effects of spice and herb extracts in poultry. They synthesized findings related to immune parameters, performance, and disease resistance. Spice and herb extracts, such as turmeric, ginger, and garlic, were found to possess immunostimulatory properties and could enhance poultry immune function and disease resistance. The study suggests incorporating spice and herb extracts into organic poultry diets as natural alternatives to antibiotics for promoting immune health. On the other hand, the current study focused on exploring the immunomodulatory effects of herbal supplements in poultry.

Secondly, a methodological gap also presents itself, for example, in their study on investigating the potential applications of spice and herb extracts as alternatives to antibiotics in organic poultry farming; Teng, Kim & Ricke (2020) conducted a literature review to compile existing evidence on the immunomodulatory effects of spice and herb extracts in poultry. Whereas, the current study adopted a desktop research method.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

After an extensive investigation into the immunomodulatory effects of herbal supplements in poultry, several key conclusions can be drawn. Firstly, the findings indicate that herbal supplements have significant potential in enhancing the immune function of poultry. Across various empirical studies, supplementation with herbal extracts consistently led to improvements in immune parameters such as lymphocyte proliferation, cytokine production, and antibody titers. These immunostimulatory effects suggest that herbal supplements could serve as valuable tools for bolstering poultry health and disease resistance.

Moreover, the studies underscore the diverse mechanisms through which herbal supplements exert their immunomodulatory effects. Phytochemicals present in herbal extracts, including polyphenols, flavonoids, and polysaccharides, interact with immune cells and signaling pathways to enhance innate and adaptive immune responses in poultry. For instance, polysaccharides stimulate macrophage activity, while flavonoids promote lymphocyte proliferation and antibody production. This multifaceted mode of action highlights the complexity of herbal supplements' effects on poultry immunity and underscores the importance of considering holistic approaches in poultry health management.

Furthermore, the research indicates that the efficacy of herbal supplements in poultry production is influenced by various factors, including the type of herbal extract, dosage, and the poultry's physiological state. Studies comparing different herbal supplements or combinations thereof reveal varying degrees of immunomodulatory effects, suggesting that the selection and formulation of herbal supplements play a crucial role in determining their efficacy. Additionally, environmental factors such as stressors and housing conditions can impact poultry immune function and may interact with herbal supplementation. Therefore, future research should focus on optimizing herbal supplement formulations and elucidating the interactions between herbal supplements and environmental factors to maximize their benefits in poultry production.

The collective evidence from empirical studies supports the notion that herbal supplements have potent immunomodulatory effects in poultry. These supplements offer promising alternatives to conventional additives like antibiotics, contributing to sustainable and holistic approaches to poultry health management. However, further research is needed to deepen our understanding of the specific mechanisms underlying herbal supplements' effects on poultry immunity, optimize their formulations for maximum efficacy, and address practical considerations such as dosage and administration methods. By advancing our knowledge in this area, we can harness the full potential of herbal supplements to promote the health, welfare, and productivity of poultry populations while reducing reliance on antibiotics and synthetic additives.

5.2 Recommendations

The findings of this study contribute to advancing theoretical knowledge in poultry immunology and pharmacology. By elucidating the immunomodulatory effects of herbal supplements, the study enriches our understanding of the complex interactions between phytochemicals and the avian immune system. These insights contribute to theoretical frameworks that explore the mechanisms underlying

host-pathogen interactions and immune regulation in poultry. Furthermore, the study provides a basis for the development of theoretical models that integrate traditional knowledge of herbal medicine with modern immunological principles, facilitating interdisciplinary research approaches in the field of ethnoveterinary medicine.

In terms of practical implications, the study's recommendations have significant relevance for poultry producers, veterinarians, and feed manufacturers. Firstly, the findings advocate for the incorporation of herbal supplements into poultry diets as natural additives to promote immune health and disease resistance. Poultry producers can leverage this recommendation to optimize flock health and productivity while reducing reliance on antibiotics and synthetic additives. Additionally, veterinarians can incorporate herbal supplements into holistic disease management programs, offering poultry farmers sustainable alternatives for maintaining flock health. Moreover, feed manufacturers can develop specialized feed formulations containing herbal supplements tailored to meet the specific immune needs of poultry, thereby supporting the production of healthier and more resilient poultry products.

From a policy perspective, the study's recommendations advocate for regulatory frameworks that support the use of herbal supplements in poultry production. Policymakers can consider integrating herbal supplements into existing guidelines for feed additives, ensuring their safety, efficacy, and standardized use in poultry diets. Additionally, policies promoting research and development in herbal medicine and ethnoveterinary practices can foster innovation and knowledge exchange in the poultry industry. Moreover, policies aimed at reducing antibiotic use in animal agriculture can incentivize the adoption of herbal supplements as viable alternatives, aligning with global efforts to combat antimicrobial resistance and promote sustainable livestock production practices.

The study underscores the importance of education and training initiatives aimed at enhancing awareness and understanding of herbal supplements among poultry stakeholders. Educational programs targeting poultry producers, veterinarians, and feed industry professionals can provide valuable information on the selection, preparation, and administration of herbal supplements in poultry diets. Training workshops and extension services can equip poultry farmers with practical skills for integrating herbal supplements into their management practices effectively. Furthermore, educational campaigns can raise awareness among policymakers and regulatory authorities about the potential benefits of herbal supplements in poultry production, fostering policy support and investment in research and development initiatives.

The study recommends fostering collaboration between academia, industry, and government agencies to further research and innovation in the field of herbal supplements in poultry production. Collaborative research projects can leverage multidisciplinary expertise to address critical knowledge gaps, such as the identification of novel herbal formulations and their mode of action on poultry immune function. Industry-academia partnerships can facilitate technology transfer and commercialization of herbal supplements, ensuring their accessibility and affordability for poultry farmers. Moreover, government funding agencies can support collaborative research consortia focused on advancing herbal medicine research and promoting evidence-based policies in animal health and welfare.

Finally, the study emphasizes the importance of international cooperation and knowledge exchange to address global challenges in poultry health and production. Collaboration between countries can facilitate the sharing of best practices, scientific findings, and regulatory experiences related to the use of herbal supplements in poultry farming. International organizations and networks can serve as platforms for dialogue and collaboration, promoting harmonization of standards and regulations governing the use of herbal supplements in poultry production. By fostering international cooperation,

stakeholders can collectively harness the potential of herbal supplements to enhance poultry health, improve food security, and promote sustainable livestock production systems worldwide.

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