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# Effects of Fermented Turmeric *(Curcuma longa L.)* as a Feed Additive on Growth Performance, Egg Quality, and Gut Microbiota of Laying Hens: A Review

**Aubrey Charm S. Tagalogon[1*], Aldrees B. Guro[2], Reymard M. Galarrita[3]**

[1] Department of Animal Science, College of Agriculture, Mindanao State University-Main Campus, Marawi City, Philippines
[2,3] Department of Agribusiness Management, College of Agriculture,Mindanao State University-Main Campus,Marawi City,Philippines

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*Correspondence: Aubrey Charm S. Tagalogon
Email: aubreycharm0712@gmail.com

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**Abstract:** The growing limitation of the use of antibiotic growth promoters in poultry farming has led to research into sustainable feed additives capable of sustaining productivity and promoting the well-being of the birds. Turmeric (*Curcuma longa L.*) is one such plant additive with antioxidative, antimicrobial, and immunomodulatory attributes. This paper provides a critical analysis of scientific articles written between 2020 and 2026 about the impacts of feeding laying hens with turmeric and the impacts of fermented turmeric on their health and productivity. However, these results show great variance depending on factors such as experimental design, dosage, duration of feeding period, bird age, and methods of fermentation. Fermented turmeric is usually associated with greater benefits compared to non-fermented turmeric. Nevertheless, the physiological basis of these benefits is not yet fully known. Fermentation may help facilitate the liberation and conversion of compounds with biological properties via microbiological processes. Nonetheless, there is no consistent proof that such conversions contribute to enhanced physiological activities. Furthermore, there have been experiments conducted with a small number of subjects under highly-controlled settings which lowered the applicability of the research to real-world commercial production. Despite these limitations, the available evidence suggests that fermented turmeric has potential as a sustainable phytogenic feed additive in poultry nutrition. Further standardized and long-term studies are necessary to clarify its mechanisms of action, determine optimal inclusion levels, and strengthen the reliability of current findings.

**Keywords:** *Curcuma Longa L*; Fermented Turmeric; Laying Hens; Growth Performance; Egg Quality

## Introduction

The poultry industry remains as one of an integral part of agriculture due to its significant contribution to ensuring affordable and nutritious sources of animal proteins. Rising global consumption of poultry products has prompted the development of intensive livestock production methods with the aim of improving feed efficiency and productivity. In many cases, antibiotics have been used as growth-promoting substances in poultry production systems to increase growth rate and prevent diseases. The extensive and long-term use of antibiotics poses considerable problems of antimicrobial resistance and

contamination of poultry meat with drug residues (Alagawany et al., 2021; Abd El-Hack et al., 2022). This has contributed to tightening regulations and restrictions associated with the application of antibiotics in animal husbandry.

In this regard, research efforts and interest have been directed towards natural and sustainable options that would not only maintain production but also enhance the well-being of animals. The use of phytogenic feed additives based on medicinal plants, spices, and herbs has gained popularity due to the properties of being antimicrobial, antioxidative, anti-inflammatory, and immunomodulatory (Khan et al., 2021; Mehdi et al., 2021). Turmeric (*Curcuma longa L.*) a member of Zingiberaceae plant family and medicinal herb, is one of the most studied phytogenic feed additives among other alternatives used in poultry nutrition. The active compound of turmeric known as curcumin shows properties of antioxidant, antimicrobial, anti-inflammatory, and hepatoprotective nature (Abd El-Hack et al., 2022; Saeed et al., 2021).

There have been several reports showing the efficacy of turmeric administration in chickens, such as improvements in the efficiency of feed utilization, egg laying, eggshell quality, egg yolk coloration, immune response, and intestinal microflora (Gowda et al., 2020; Bozkurt et al., 2021). However, there is still some inconsistency among the results obtained from other reports. Some authors found minimal changes in productive performance due to insufficient or incorrect levels of turmeric inclusion or differences in management practices. Moreover, variations in chicken strains, ages, external conditions, and feeding periods have made comparisons difficult.

Recently, there has been a growing interest in the use of fermented turmeric as a possibly superior source for supplementation. The term “fermentation” refers to the microbial alteration of plants via microbial metabolism using microorganisms such as lactic acid bacteria and yeast. The fermentation process could result in changes in the composition of turmeric by breaking down bound substances, converting curcuminoids, and minimizing some anti-nutritional elements. Nonetheless, the hypothesis that fermentation always enhances turmeric activity is still questionable. Various fermentation microorganisms, conditions, time, and product quality may affect the quantity and stability of active substances, causing variations in biological activities from one study to another. There is inadequate information about standard fermentation processes and the biochemical mechanisms behind the biological actions of fermented turmeric on laying hens.

Despite the presence of several studies on the inclusion of turmeric into the diets of poultry birds, little has been done by way of critical evaluation of the use of fermented turmeric in laying hens. Most reviews focus more on the positive attributes of using turmeric in poultry diets rather than the inconsistencies in some results obtained from these studies, possible weaknesses in methodologies employed, and the inconsistency in the process of fermentation. Furthermore, little has been said about how consistent the currently available evidence is when used in commercial environments. Therefore, this review aims to critically evaluate current literature on fermented turmeric supplementation in laying hens, with emphasis on its effects on productivity, egg quality, gut health, and the limitations and research gaps that require further investigation.

## Research Methodology

This research used a qualitative research method based on a systematic literature review to investigate the impact of fermented turmeric (*Curcuma longa L.*) as a dietary supplement on the growth performance, egg quality, and gut microbiota of laying hens. The main objective of this research method is to integrate and analyze the current body of scientific knowledge regarding the general impacts, reliability of results, and research gaps concerning the use of turmeric as an additive in poultry diets. As the research does not include any experimental work, all the necessary information was sourced from the scientific literature.

Data sources used for this research work were obtained from credible scientific databases including Google Scholar, ScienceDirect, SpringerLink, PubMed, and various other academic journals. To ensure that the latest data is being used, the literature that has been considered for this study pertains to research conducted during the period of 2020-2026. To this literature review, the articles that were selected pertain to the effect of turmeric (*Curcuma longa L.*) as a dietary supplement in poultry production. In addition, articles which discuss the effect of this substance on laying hens, broilers, ducks, and other poultry have also been considered.

Inclusion and exclusion criteria were applied while selecting the articles. Those articles were included whose studies (1) were concerned about either the use of turmeric as a feed additive or its fermentation, (2) were conducted using poultry species including layers, (3) had shown results related to productivity measures such as egg production rate, feed conversion efficiency, egg quality characteristics, microbial changes, or physiology, and (4) were from peer-reviewed publications. On the other hand, studies that were irrelevant to poultry nutrition, lacking proper research designs, or having insufficient information about performance or physiology were excluded from the review.

Once the selection process was complete, the data was sorted and analyzed through thematic analysis. The information collected from each of the studies was sorted according to specific variables, which included growth performance, egg production, egg quality traits, modulation of gut microbiota, immune response, and blood biochemical parameters. It is through this process that data can be compared from one study to another. Specifically, there was emphasis on the preparation of turmeric (raw powder, fermented turmeric, or turmeric plus probiotics), amount of dosage, duration of the feeding trials, and other possible reasons for variability in results.

In addition, comparison was made among the studies used to see where the similarities and differences lay. This was done to establish whether fermented turmeric indeed had better results than raw turmeric or any other plant-derived feed supplement. The various methodologies used by each study were reviewed, particularly the number of samples used, experimental methodology, type of poultry used, environmental variables, and method of administration of feed.

For the sake of ensuring the accuracy and reliability of the review, only peer-reviewed and scientifically accepted publications were selected. In the process of assessment of each publication, attention was paid to its methodology, statistical

calculations, and evidence-based approach. The results obtained from each study were compiled in an objective manner, they remained unchanged. At the same time, contradictions that appeared during analysis of some research works were mentioned.

In summary, this methodological framework offers a systematic way of investigating the scientific literature on the impacts of fermented turmeric on poultry nutrition. Through a synthesis of results obtained from several studies, this review seeks to provide an informed perspective on how fermented turmeric affects layer chickens. This methodological framework ensures that all the conclusions reached are backed by reliable and recent scientific sources.

## Literature Review

### Turmeric as a Phytogenic Feed Additive in Poultry Nutrition

Phytogenic feed additives are those natural components derived from herbs, spices, and medicinal plants used in poultry feed to enhance the growth and welfare of the animals. As per Alagawany et al. (2021), phytogenic feed additives have been found to offer various benefits including anti-microbial action, antioxidant potential, and improving the digestion process of the animals. Of all the phytogenic feed additives currently being researched, turmeric has proved to be an exceptional one due to its biological effects on curcumin. According to Abd El-Hack et al. (2022), curcumin is a natural antioxidant that prevents oxidative damage to cells and boosts metabolic functions in poultry. Curcumin has antibacterial and anti-inflammatory effects that keep the intestine healthy and boost the body's immunity. Turmeric has been proven to enhance productivity while reducing the incidence of diseases in poultry farming.

Several studies have established the beneficial impact of turmeric in poultry feeding. Rajput et al. (2020) noted that dietary inclusion of turmeric was beneficial for enhancing growth rate and maintaining gut integrity in poultry birds. The study showed increased feed efficiency and better gastrointestinal function in poultry birds supplemented with turmeric. In another study, Saeed et al. (2021) suggested curcumin as a natural growth promoter which enhanced performance in poultry birds without causing any harm that results from antibiotic supplements. The increasing use of turmeric in poultry nutrition can be attributed to several factors, but mostly because of its multifunctional nature. While antibiotics are mainly concerned with disease management, turmeric ensures improvement in digestive process, metabolic rate, immune response, and antioxidant activity of the body. This is why turmeric is considered as a viable natural feed supplement in poultry farming.

### Effects of Turmeric on Growth Performance and Feed Efficiency

Turmeric supplementation in poultry is typically analyzed using experimental research approaches to assess the impact of the herb on growth performance and feed utilization. For instance, in the experiment by Kasri et al. (2024), Isa Brown layer hens were assigned to various groups that received varying amounts of fermented turmeric supplement in their diet. Fermented turmeric was made through a microbiological

fermentation process aimed at increasing curcumin availability. The animals were housed and fed under controlled conditions, and information such as egg yield, feed consumption, and feed utilization were recorded for a certain period. The findings indicated that chickens treated with fermented turmeric produced better quality eggs with higher conversion efficiencies than those in the control treatment. During the discussion of the experiment, the researchers highlighted that the process of fermentation increased the efficacy of curcumin, which might contribute to better nutrient utilization and productivity among the birds.

In a similar way, Moniei et al. (2024) performed an experimental study by using broiler chickens in two different groups (control group and turmeric-fed). The two groups were fed with formulated diets with varying levels of turmeric powder or extract. During the duration of the trial period, the authors monitored the body weight gain, feed intake, and feed conversion ratio of the broilers for growth assessment. Poultry farming practices were applied to maintain the same environment throughout the experiment. The results indicated that broilers supplemented with turmeric had higher body weight gain and better feed conversion ratio than control group broilers. It was discussed that turmeric can increase digestive enzyme secretion due to its antimicrobial and antioxidant properties.

On the other hand, Ogbuewu et al. employed the meta-analytic method of research to examine the impacts of dietary turmeric supplementation on productive performance of commercial layers. Data was gathered and analyzed through a review of several scientific studies published on the impacts of turmeric supplementation in diet on layers. Certain inclusion and exclusion criteria were set up for study selection purposes, while statistics were used to compare and synthesize the impacts of turmeric on productivity factors. This procedure enabled the scientists to determine the prevailing trends and establish the effectiveness of the application of turmeric supplementation among different research and different types of poultry production. From the findings, the application of turmeric in the form of a supplement to poultry had effects on increasing efficiency of feed utilization, increased egg production, and increased productivity in general in the production of poultry. Turmeric was suggested by the researchers as an effective method for improving intestinal microflora in this discussion part.

**Effects of Turmeric on Egg Quality**

Several research works have been done on the effects of turmeric supplementation on egg quality using experimental research approaches. For instance, the study by Mosayyeb Zadeh et al. (2023) included a feeding experiment involving laying hens in two groups, one being the control group while the other one was supplemented with turmeric. Various concentrations of turmeric powder were added to the diet of the chickens in different proportions for the evaluation of the quality of the eggs produced. Such qualities included yolk color, shell thickness, albumen quality, and the cholesterol level. The study found out that egg qualities of the supplementing hens were better than those from the control group.

Likewise, Li et al. (2023) conducted an experimental research study on laying hens where curcumin was used to supplement their diet. The researchers evaluated the quality

attributes of eggs and the lipid metabolism and liver functions of the hens. The results indicated that curcumin supplementation enhanced the egg qualities and had a positive effect on the lipid metabolism of liver tissue. During the discussion, the researchers recommended that curcumin regulates the liver function and fat metabolism, which play a crucial role in egg production and quality.

Additionally, Ardiansyah et al. (2022) conducted experiments where turmeric was used in conjunction with Lactobacillus strains in ducks. Their intestinal health and egg quality traits were assessed during feeding experiments. The findings indicated that the use of turmeric along with probiotics improved the intestinal tract and egg quality traits in ducks. In their discussion section, the authors stated that the mixture of turmeric and probiotics would improve the absorption and digestion of nutrients, resulting in increased egg production and egg quality. Moreover, they pointed out that natural colors from turmeric made the eggs look appealing.

**Effects of Turmeric on Gut Microbiota and Immune Response**

Several studies have been conducted to explore the impacts of turmeric supplementation on the gut and immune system of poultry animals through experiments. In this regard, the study by Tian et al. (2022) focused on the provision of fermented plant-based feed containing turmeric to laying hens. The study was conducted through experiments, where the laying hens were fed under laboratory conditions. The scientists carried out microbiological and intestinal analysis to measure the impacts of the feed provided to the birds on their health. The findings of the study indicate that the laying hens that consumed fermented turmeric supplements contained higher numbers of good bacteria and lower numbers of pathogenic bacteria.

In a similar manner, Recharla et al. (2021) conducted an experimental study where turmeric was added to the diet of poultry birds, and their gut microbiota along with short-chain fatty acid production were analyzed since they act as major indicators of gut health. It was found that the addition of turmeric resulted in an increase in the numbers of helpful bacteria as well as increased short-chain fatty acid production in their bodies. The authors discussed that the use of turmeric can lead to an improvement in the gut microbiota environment.

Another study by Seidavi et al. (2023) analyzed the impacts of phytogenic feed additives such as turmeric on the immune system of poultry birds. In this experiment, diets of the poultry birds were supplemented with phytogenic substances, and their immune parameters were measured under managed settings. According to the findings, adding turmeric to the diet boosted immune reactions and increased resistance to disease among the poultry birds. During the discussion of the paper, the researchers pointed out the antioxidant and anti-inflammatory effects of curcumin for alleviating oxidative stress and enhancing the immune system of the body. In addition, it was suggested that turmeric could be used as an effective substitute for antibiotics in growth-promoting programs for poultry.

**Fermented Turmeric Compared with Other Feed Additives**

Experimental studies have been frequently used when evaluating the effectiveness of turmeric compared to other plant-based feed additives for their effects on the performance of chickens and the improvement of production levels. Li et al. (2025) did an experimental study where they used chickens that were separated into various diet treatments involving turmeric, ginger, and turmeric and ginger. Chickens were reared in specific conditions, and their growth performance, gut microflora, feed efficiency, and other variables were recorded throughout the experiment. The study was performed to measure the effect of dietary treatment. It was observed that chickens that were supplemented with the mixture of turmeric and ginger performed better in terms of growth, feed efficiency, and had improved intestinal microbiota when compared to other groups. Also, the mixture helped increase the number of beneficial gut microbes and lowered the number of pathogens. In the discussion section, it was stated that the reason behind their synergy might be since they both have bioactive compounds with antioxidant, antimicrobial, and digestive benefits.

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Experiments involving the fermented turmeric extract have also widely been performed in poultry birds. In such experiments, fermented turmeric was produced via the process of microbial fermentation to enhance the absorption of curcumin and other compounds in it prior to the inclusion of the fermented product in the poultry diet. Fermented turmeric was then compared with non-fermented turmeric in terms of its effects on the growth performance and feed utilization efficiency of the poultry birds.

It was found that fermented turmeric consistently performed better compared to plain turmeric powder, especially in terms of enhancing nutrient absorption, digestion, and production performance. In the discussion section, the researchers noted that fermentation could increase curcumin bioavailability and introduce good microbes, which help maintain the microbiome equilibrium of the intestines. This could increase efficiency in digestion and improve the overall performance of the chickens. Due to the benefits provided using fermented turmeric, most of the studies conducted on poultry nutrition now combine it with probiotics.

## Result and Discussion

Turmeric (*Curcuma longa L.*) is found to have positive impacts on poultry production, either in its original form or in a fermented form, as seen from the literature reviews done (Abd El-Hack et al., 2022; Ogbuewu et al., 2022). The positive impacts associated with turmeric include increased egg production, efficiency in feed utilization, improved egg

quality, gut health, antioxidative activity, and immune responses, where turmeric was included in the diet of poultry (Seidavi et al., 2023; Alagawany et al., 2021). From the results obtained from these studies, it is evident that turmeric has great potential to be used as a natural alternative to antibiotics due to the issue of resistance (Alagawany et al., 2021).

One important observation made from the review of literature is the tendency of fermented turmeric to yield much better effects compared with normal turmeric powder. While regular turmeric powder has been proven to contain various active ingredients like curcumin, their effectiveness may be reduced owing to low bioavailability (Li et al., 2023). The implication of this fact is that curcumin in raw form may not yield the maximum biological activity when ingested because a significant amount does not get absorbed in the body. This occurs due to the presence of the plant cell walls which prevent most of the curcumin from being digested effectively (Li et al., 2023; Tian et al., 2022). However, fermentation removes this obstacle since microorganisms such as yeast and Lactobacillus sp. can digest the plant cell wall (Tian et al., 2022).

Additionally, fermentation generates more helpful elements like organic acids, digestive enzymes, vitamins, and probiotics. The generation of these substances enhances the intestinal environment and promotes the proliferation of good bacteria within the gastrointestinal tract (Recharla et al., 2021). The enhanced microbial balance in the gut enables the poultry to digest food more effectively and absorb the nutrients properly. Birds will be able to convert the food into eggs or body mass more effectively due to this (Ogbuewu et al., 2022; Recharla et al., 2021). This is the reason that most studies with fermented turmeric yielded superior results than studies with regular turmeric powder (Abd El-Hack et al., 2022; Ogbuewu et al., 2022).

According to Kasri et al. (2024), fermentation of turmeric led to better egg production and feed utilization in Isa Brown laying hens. The researchers found that fermentation enhanced phytochemicals and antioxidants in turmeric, thereby improving metabolic function in poultry animals. Likewise, Tian et al. (2022) found that fermenting plants provided benefits to laying hens in terms of enhanced intestinal barrier and cecal microbiota composition. The laying hens exhibited greater bacterial population and intestinal integrity, thus facilitating efficient nutrient absorption and enhanced immunity.

In addition to other biological actions, turmeric is believed to possess more widespread biological activities than other feed additive substances. Garlic is widely recognized for its antibacterial effects, whereas ginger can be effectively used as a digestive stimulant and appetite booster. Probiotics are usually capable of enhancing microflora of the gastrointestinal tract. Essential oils might positively influence digestion and immune system due to different chemical composition. Turmeric is characterized by more than one type of biological activity. It can act as an antioxidant, antimicrobial substance, anti-inflammatory agent, immune system enhancer, and lipid metabolism regulator.

The differences between the studies become even clearer when considering the biological impacts of each. In terms of the impact of the product on the microbial flora of the gastrointestinal tract, probiotics can have a more pronounced effect due to the presence of live organisms in their composition. Turmeric possesses antimicrobial and antioxidant

properties; it supports liver and lipids metabolism as well. It is possible to argue that garlic can eliminate detrimental bacterial flora, but it is incapable of providing the same level of antioxidant impact, which is associated with curcumin. Ginger helps improve digestion and stimulate appetite; however, its immunostimulant effect is less noticeable compared to the one of turmeric supplementation.

Additionally, according to Li et al. (2025), there could be synergistic effects between turmeric and ginger in terms of the additive efficacy. In other words, the additives would work more efficiently in combination as compared to their individual application. The benefits of applying the additives together were revealed through improved performance of poultry, changes in serum chemistry, and modification of gut microflora.

**Table 1.** *Comparative Analysis of Turmeric and Other Phytogenic Feed Additives in Poultry Nutrition*

| Feed Additive | Main Function | Main Benefits | Weaknesses | Comparison with Turmeric |
|---|---|---|---|---|
| Fermented Turmeric | Enhanced antioxidant and probiotic effects | Better digestion, stronger microbial balance, improved nutrient absorption ((Kasri et al., 2024; Tian et al., 2022) | More expensive and requires processing | Fermented turmeric is **more effective due to bioavailability and gut effects** |
| Garlic | Antibacterial activity | Reduces harmful bacteria ((Alagawany et al., 2021) | Limited antioxidant effects | Has a narrower effect compared to turmeric's wider health benefits |
| Ginger | Digestive stimulant | Improves appetite and digestion ((Li et al., 2025) | Less effect on immunity and egg quality | Works well with turmeric but is not as broad in action |
| Probiotics | Gut microbial regulation | Improves intestinal health ((Ardiansyah et al., 2022) | Results depend on bacterial strains | Stronger for gut microbes, but weaker in antioxidant effects than turmeric |
| Essential Oils | Digestive and immune support | Improves feed palatability and immunity ((Mehdi et al., 2021) | Effects depend on oil composition (Mehdi et al., 2021) | Has useful effects but not as wide-ranging as turmeric |

Although there are certain advantages to turmeric supplementation, there are certain limitations associated with its practical usage in the commercial poultry industry. The majority of research articles reviewed in this paper have used experimental or lab settings wherein feed consumption, environmental factors, and the general health of birds are tightly controlled. However, there are many variations and stressors in commercial poultry farming that make it challenging to implement the findings from experiments. Farmers are generally reluctant to incorporate any new feed additives unless they are economically feasible (Abd El-Hack et al., 2022; Seidavi et al., 2023).

Turmeric fermentation could also be more costly to undertake since the process involves microbial culture and control, which raises the cost of production than raw turmeric powder. According to Tian et al. (2022), it would not be easy for small poultry farmers to ferment turmeric owing to resource and technical constraints. In addition, variations in the composition of turmeric resulting from different plant varieties, weather conditions, harvest times, and processing techniques affect the level of bioactivity and curcumin content of the product (Li et al., 2023). Commercial production relies on standardized processes to ensure consistency of the product, which would be impossible in this case.

Nevertheless, turmeric use could prove to be economically profitable in the long run due to several reasons. Firstly, higher efficiency in terms of feed utilization will result in increased nutrients absorption and lower wastage. Secondly, improved gut health and immunity levels will lead to reduced chances of diseases, which implies that less money would be spent on antibiotics. Thirdly, the improved quality of eggs in terms of thicker shells and better pigmentations would bring more economic benefit.

Moreover, fermented turmeric would seem more appropriate for the poultry farms on a moderate and large scale that have access to sophisticated feed processing systems. On the other hand, ordinary turmeric powder could continue being more viable for the small-scale farmers because of their convenience and affordability. Nonetheless, in case of any future breakthroughs in simplifying and making the fermentation process cheaper, fermented turmeric will become more popular in the poultry industry.

The other limitation could be publication bias. Most studies have indicated positive benefits from taking turmeric supplements, whereas studies demonstrating insignificant or non-existent results are rarely found in scientific literature, leading to possible exaggeration of its efficacy (Alagawany et al., 2021).

In addition, most experiments lasted for a short period of time and were performed in laboratory settings. On the contrary, commercial poultry production experiences continuous exposure to stress, diseases, and varied management strategies, which might lead to inconsistencies in outcomes (Seidavi et al., 2023). Variations in dose, breed of chickens, duration of experiments, and type of turmeric (powdered, fermented, or probiotic) are some factors that can result in inconsistencies across various research works (Tian et al., 2022; Li et al., 2025).

Generally, it is well established that turmeric, especially fermented turmeric, can enhance the performance, egg quality, gastrointestinal tract condition, antioxidant levels, and immunity in poultry (Kasri et al., 2024; Ogbuewu et al., 2022). As opposed to other natural feed supplements, turmeric displays more widespread biological functions due to its antioxidant, antimicrobial, anti-inflammatory, immunomodulating, and lipid-regulating activities (Abd El-Hack et al., 2022). Nevertheless, there are significant issues that need to be addressed, such as cost-effectiveness, commercial scalability, standardization, and possible publication bias. Further studies should be conducted concerning large-scale field trials and the cost-benefit ratio of turmeric use in the poultry industry.

## Conclusion

As can be observed from the reviewed literature, Turmeric (*Curcuma longa L.*) in particular in its fermented form is highly promising as a natural feed additive in poultry farming. Almost all studies mentioned have documented favorable results with respect to egg production, feed conversion rate, egg quality, gut function, immunity, and performance of poultry. The benefits associated with turmeric in poultry farming have been attributed mainly to its antioxidant, antimicrobial, and anti-inflammatory activity of curcumin. However, the results in some studies were more favorable with fermented turmeric owing to enhanced curcumin bioavailability and balanced intestinal microbiota.

Another important finding from the reviewed studies is that turmeric can be used as a safe and viable alternative to antibiotics in promoting animal growth. Given the rise in antimicrobial resistance and the limitations of antibiotic use in the production of animals, it becomes clear that turmeric supplementation can help achieve the desired goal sustainably. As compared to other feed additives like garlic, ginger, probiotics, and essential oils, the role played by turmeric was more pronounced because it positively impacted digestion, immune system, antioxidants, and metabolism of animals.

Despite these positive results, some limitations within the existing body of knowledge on this topic were also noted. The inconsistencies between the doses administered, the variations in the formulations of turmeric used, the types of birds being studied, the time span involved, and the environmental settings made comparing the different research works challenging.

Furthermore, most of the studies done in the laboratory setting, and for only a short period. There have not been enough commercial-level studies carried out yet. Publication bias may also play a role since the tendency is that studies with positive findings get published compared to those with less conclusive or negative outcomes. Nevertheless, based on what we have discussed above, one can safely say that there is still enough data to make the study relevant from scientific and practical perspectives. Consistency of positive results obtained using various poultry types, research methods, and experimental designs indicates the significance of turmeric as an additive for enhancing poultry production and health. Experimental and review papers, as well as meta-analyses, prove that adding this substance can lead to productive results for poultry health and productivity if done correctly.

The findings of this review have several important implications not only for the producers of poultry but also for researchers working in this field. The positive effect of turmeric, especially fermented turmeric, has been proven consistently. It indicates the potential for a sustainable use of this feed supplement to benefit the health and productivity of birds while limiting their reliance on antibiotic growth promoters. Poultry producers may find it useful to add this compound to the diets of their livestock as an environmentally friendly and cost-effective solution. Still, appropriate consideration should be paid to the dosage and the methods used to prepare the supplement along with selecting the appropriate strain of chickens. In the area of further scientific research, the necessity of

conducting long-term investigations in commercial farms arises. They are needed to find out the best levels of supplementation and calculate the economic efficiency of this method.

Overall, the literature reviewed that turmeric, especially fermented turmeric can serve as an excellent choice for a potential feed supplement in poultry farming. Although more research is needed in order to confirm the efficacy of such products on both a commercial and standardized basis, the existing literature already proves that turmeric can be used in sustainable antibiotic-free poultry farming. Hence, the above literature review can be regarded as a credible source for future research on feed supplements in poultry.

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