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Effect of turmeric powder on egg quality, gut morphology, ecology and on immune system of laying hen: A review

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Abstract
The growing concerns of consumers on the use of antibiotic as a growth promoter in livestock feed have fuelled the interest in alternative products. In the recent years a group of natural product known as phytogenic has been a focus of several studies. Phytogenics are a heterogeneous group of feed additives originating from plants and consist of herbs, spices, fruit, and other plant parts. These feed additives are reported to have a wide range of activities including antimicrobial, anthelminthic, antioxidant, growth enhancer, and immune modulator. The active substances in the turmeric oil are Curcuminoids, aromatic turmerones (32.5%), alpha (15.6%) and beta turmerones (17.1%) and curlone. Curcuminoids have a wide spectrum of biological activities including antioxidant, antibacterial, antifungal, antiviral and anti-inflammatory property. They include many different bio-active ingredients such as alkaloids, bitters, flavonoids, polyphenols, terpenoids. These feed additives have been tested in the form of extracts, essential oils in a number of animals but the results are variable. Therefore, their application as feed additive has been limited, largely owing to their inconsistent efficacy and lack of full understanding of the modes of action. The aim of this review is to summarize on the current knowledge on the use of turmaric powder as a feed additive in monogastric animal.

Keywords: Antibacterial, antioxidant, antiviral, curcuminoids, phytogenics, polyphenols

Introduction
Indian poultry industry has emerged as one of the fastest growing segment of the agriculture sector of the country over the past decade. The layer sector has been the most profitable segment in poultry due to its marginal investments and easy returns. Poultry farming has undergone a paradigm shift in structure and operation, transforming itself from a mere backyard activity into a major commercial venture. Antibiotics have been used as antimicrobial growth promoters (AGP) in animal to improve food safety. However, in order to avoid the possible risk of developing resistant pathogens, as well as to meet the public pressure of antibiotic free animal products, the use of antibiotic in poultry diet was totally banned in European Community. In order to reduce the disadvantage of sub-clinical and clinical infections, the poultry feed industries needs to find alternatives to AGPs. Various alternatives of green additives have been studied in order to maximize the growth performance of poultry in the diets without antibiotics. The active substances in the turmeric oil are curcuminoids [1] aromatic turmerones (32.5%), alpha (15.6%) and beta turmerones (17.1%) [2] and curlone [3]. Curcuminoids have a wide spectrum of biological activities including antioxidant, antibacterial, antifungal, antiprotozoal, antiviral, anticoccidial and anti-inflammatory property [4].Turmeric is one supplement that can modulate the lipid profile and cholesterol content [5]. Curcumin was also found to affect lipid metabolism, and inhibit lipid peroxidation [6]. Hypocholesteremic effect of turmeric is due to its coloring principle, Curcumin. Curcumin was effective in reducing both liver and serum cholesterol level [7].
The literature available on use of turmeric powder as feed additive in the ration of laying hens is scanty. However, an effort has been made to review the available literature has and is presented under the following heads:

Effect on Egg Qualities
Egg mass
Addition of turmeric at 0.50 or 1% significantly increased the egg mass when compared with the control diets [8]. Different levels of turmeric powder had no effect on egg mass production

in separate weeks, however 2 g/kg turmeric powder significantly (P<0.05) increased egg mass production over the 4 weeks assay [9, 10]. Found that inclusion of turmeric root at level of 2% in the diet did not affect (P<0.05) egg mass significantly in the birds when compared to the basal diet [11]. reported that supplementation of turmeric at 10.0 or 30.0 g/kg did not influence egg mass of single comb white leghorn laying hens [12]. Reported that egg mass in the groups fed diet with turmeric powder were significantly higher than that of the control (P<0.05) [13]. Reported that turmeric powder at 5 or 10 g/kg feed showed significant increase (P<0.05) in the egg mass [14]. Reported that the dietary supplementation of turmeric powder at 4% significantly (P<0.05) decreased the egg mass in laying hens as compared to hens fed turmeric powder at 2% level and control group.

Egg weight

Egg weight increased significantly after feeding turmeric at 0.50 or 1% as compared to the control diets [8, 11]. Found that supplementation of turmeric at 10.0 or 30.0 g/kg did not influence egg weight of single comb white leghorn laying hens. Egg weight was not affected by dietary supplementation of different levels of turmeric powder (P>0.05) [15, 10]. Found that inclusion of turmeric root at level of 2% in the diet did not affect (P<0.05) egg weight significantly in the birds when compared to the basal diet [14]. Reported that the dietary supplementation of turmeric powder at 2% significantly (P<0.05) decreased the egg mass in laying hens as compared to hens fed turmeric powder at 4% level and control group [12]. Found that egg weight in the groups fed diets with 0.50% turmeric powder was higher than that in the other groups [16]. Reported that turmeric supplementation up to 4% did not affect egg weight [17]. Reported that supplementation of turmeric powder had no significant effect on egg weight in laying hens as compared to control groups.

External and internal egg qualities

Addition of 0.50-1% turmeric to hen's diet numerically increased the percentage of egg shape index, shell weight and shell thickness [8]. The highest numerical value observed in shell weight and egg shape index were for 1% *Curcuma longa* [11]. Reported that feeding of turmeric at 10.0 or 30.0 g/kg did not influence egg production, egg weight and egg mass of single comb white leghorn laying hens [9]. Reported that feeding different levels (0.0, 0.50, 1.0, 1.5 and 2.0 g/kg turmeric powder of feed) to the laying hens had non significant effect on specific gravity, egg shell thickness, egg shell weight and eggs shell weight to egg weight ratio. In another study with annatto extract and turmeric [18], did not observe any influence on egg quality traits. Haugh unit of group fed diet with turmeric was higher than that of control on the 14 day of storage (P<0.05). Dietary turmeric in layer fed has beneficial effect in the change of haugh unit during storage [12]. The increased in total number of egg production did not decrease egg quality as indicated by egg weight, yolk index, egg shell index and haugh unit. Turmeric powder administration and ration quality did not affect egg weight, yolk index, egg shell index and haugh unit [19, 20]. Addiition of turmeric at 1% numerically increased yolk color then the control groups. Turmeric at level 1% increased percentage of yolk weight and improved yolk color compared to control group [8, 14]. Reported that the dietary supplementation of turmeric powder at 2 and 4% had no significant difference on haugh unit in laying hens as compared to control group [17]. Reported that supplementation of turmeric powder had no significant effect on external and internal egg qualities in laying hens as compared to control groups.

Egg yolk fatty acid profile

The hens fed 1% turmeric significantly decreased the yolk total lipid. Hens fed 0.50 or 1.0% turmeric powder recorded the lowest values of yolk LDL-cholesterol and total cholesterol [8]. Turmeric powder could reduce cholesterol by increasing the activity of cholesterol-7-α hydrolase or inhibit the activity of HMG Co-A reductase [11]. Curcumin stimulated the conversion of cholesterol to bile acid, a path to eliminate the cholesterol from the body [21]. Curcumin increased the excretion of cholesterol [22]. Turmeric powder reduced the levels of cholesterol and triglycerides in the blood in birds [19, 20]. Curcumin inhibited the absorption of dietary cholesterol [23]. Curcumin acted as an antiatherogenic agent [24], which caused blood cholesterol levels to decrease so that cholesterol transferred into the egg decreased. Supplementation of turmeric powder increased follicular hierarchy [19, 20] so that the cholesterol formed distributed into developing follicular hierarchy, thereby decreased cholesterol levels in eggs. Cholesterol in eggs was influenced by genetic factors, diet composition [25]. Curcumin induced changes in the expression of genes involved in cholesterol homeostasis [22, 19, 20]. Found that carbohydrate and protein contents of the ration did not affect egg triglyceride concentration but birds fed high carbohydrate ration had higher egg cholesterol and protein concentrations (P<0.05) irrespective of turmeric supplementation. Turmeric powder supplementation, regardless of period of supplementation, decreased cholesterol concentration of the eggs (P<0.05). Cholesterol content in the egg produced by laying hens fed dietary turmeric powder was decreased significantly (P<0.05), and the decrease was maintained along the experiment. The results indicated that cholesterol content of the egg produced by the control group tended to increase up to 6%, while it was decreased up to 16, 24 and 25% (P<0.05) by those of 1, 2 and 4% turmeric supplementation groups respectively [16, 26]. Reported that dietary supplementation of turmeric powder at 2% level along with hempseed (*Cannabis sativa*) significantly (P<0.05) increased the saturated and mono unsaturated fatty acids. But, mean values of poly unsaturated fatty acids were significantly (P<0.05) decreased as compared to the control treatment [27]. Stated that that dietary supplementation of turmeric powder at different levels had no significant (P<0.05) effect on the unsaturated fatty acids. But, mean values of saturated fatty acids were increased significantly (P<0.05) at 0.75% level of turmeric powder supplementation. There was no significant effect on mono and poly saturated fatty acids in laying hens supplemented with turmeric powder at different levels.

Intestinal morphology

[28] Found that the duodenal villi heights were significantly higher in birds fed turmeric powder at level of 200 mg/kg at 21 and 42 day. The jejunum villi heights were significantly higher in birds fed turmeric powder at level of 200 mg/kg at 21 day and in birds fed turmeric powder at level of 100 mg/kg feed at 42 day; while, ileum villi heights were significantly higher in birds fed turmeric at 150 and 200 mg/kg levels, in comparison with control and 100 mg/kg level groups at 21 and 42 day. He also found that the duodenal villi width was significantly higher in birds fed turmeric at 200 mg/kg level at 21 day; while, at 42 day, control and group fed turmeric at 150 mg/kg exhibited more width. There were no significant differences in jejunum villi width and ileum villi width among

the groups. Furthermore, jejunum villi width at 42 day was significantly more in birds fed turmeric at 150 mg/kg and 200 mg/kg level, as compared to control group and the depth of intestinal crypts in Curcumin supplemented groups was significantly less for all segments except for jejunum at 42 day of small intestine, as compared to those of control group. Likewise, the duodenum, jejunum and ileum, villi height to crypt depth ratios were higher in bird fed turmeric at 200 mg/kg and 150 mg/kg level as compared to control group [29]. Stated that the turmeric feeding to birds significantly increased the intestinal villi length than control. However, villi width, crypt length and crypt width were not altered among the groups. This increase in the intestinal villi length could be attributed to the turmeric effect on gut health by reducing intestinal pH, bacterial load and selectively increasing *Lactobacillus* count [30]. The bile duct epithelial fold length was significantly increased in broiler chickens fed turmeric. Turmeric has been known to produce hyperplasia of bile duct muscles and increase bile flow output [31]. Stated that intestinal morphology in the duodenum; jejunum and ileum were not generally affected by BCS (black cumin seed).

Phenolic compounds administration like Curcumin may reduce gut inflammation, improve digestibility of nutrients and metabolism [32]. Antioxidants present in turmeric powder may effectively scavenge the generated free radicals caused by stress, consequently resulting in improved ileal morphology. The villi: crypt depth ratio is an indicator of the likely digestive capacity of the small intestine. An increase in this ratio corresponds to an increase in digestion and absorption [33]. Increased intestinal villi height and the ratio villi height to crypt depth is an indication of the vast area for nutrient absorption and higher absorption function [30]. Thinner intestinal epithelium enhances nutrient absorption and reduces the metabolic demands of the gastrointestinal system [34]. Thinning of the gastrointestinal walls tract may be due to the inhibition of the microbial production of polyamines and volatile fatty acids, known to increase enterocyte turnover rate and activity. This increased net energy committed to maintaining the luminal tissue comes at the expense of more productive purposes such as muscle accretion [35]. Antioxidants may effectively scavenge the generated free radicals caused by heat stress, consequently resulting in improved ileal morphology [36].

Bacteriological assay

Turmeric has been reported to exhibit antimicrobial properties and ethanol turmeric extract demonstrated high potential to inhibit some pathogenic bacteria of chickens [37]. Thus like antibiotics, turmeric could control and limit the growth and colonization of numerous pathogenic and non-pathogenic species of bacteria in the bird's gut resulting in balanced gut microbial ecosystems that lead to better feed utilization reflected by improved feed conversion ratio [38]. Reported that colony forming units of *Coliform* bacteria, yeast and mould as well as total viable microbes in broiler gut contents were markedly reduced ($P<0.05$) when the diet was supplemented with turmeric powder, mannon-oligosaccharide or virginiamycin. There was no significant effect of additives on coccidial population in the broiler gut [29]. Stated that the intestinal microbial count was significantly reduced ($P<0.01$) by 45, 54, 56 and 48% in 0.25%, 0.50% 0.75% and 1.0% turmeric fed groups respectively compared to control. Similarly, *Lactobacillus* count was significantly higher ($P<0.01$) in 1.0% turmeric fed group compared to other groups [39]. Found that turmeric alcoholic extract (10-200 mg/ml) inhibited the growth of *Lactobacillus* in vitro. The higher number of *Lactobacillus* count in 1% turmeric fed chicks might be due to stimulatory effect at higher level of turmeric in feed [40]. Reported that plant extract supplement also significantly increases the *Lactobacillus* numbers following an application of natural plant extract [41]. Studied the effect of different dietary levels of *Nigella sativa* seed powder on *E. coli* and total viable bacterial count in excreta of broilers. Both *E. coli* and total bacterial counts were significantly decreased by *Nigella sativa* seed powder supplemented diets irrespective of inclusion levels [31]. Stated that the counts of total bacteria, *E. coli*, *Lactobacillus sp.*, and *Clostridium sp*. were not affected by black cumin seeds (BCS) and AB (antibiotic growth promoters) compared with the control But, *Salmonella sp*. decreased linearly with increasing doses of BCS.

Expression level of TLRs

[42] Reported that Curcumin attenuates Concanavalin A-induced liver injury in mice by inhibition of Toll-like receptor (TLR) 2, TLR 4 and TLR 9 expression [43]. reported that dietary supplementation of turmeric powder to birds significantly decreased the expression level of toll like receptors as compared to the birds fed with control diets [44]. Found that supplementation of Curcumin (a component of turmeric) in the diets of humans affect the expression of toll like receptors. Since Curcumin has been shown to affect the expression of many genes, he first screened several groups of TLRs that may be involved in the recognition of invading pathogens in monocytes and neutrophils. The mRNA expression levels of TLRs in Curcumin treated human monocytic THP-1cells and neutrophilic-differentiated HL-60 cells were analyzed using semi-quantitative RT-PCR in this screening. Significant changes were seen only in mRNA level of TLR 2.

Conclusion

Turmeric powder could reduce cholesterol by increasing the activity of cholesterol-7-α hydrolase or inhibit the activity of HMG Co-A reductase. Curcumin stimulated the conversion of cholesterol to bile acid, a path to eliminate the cholesterol from the body. Turmeric feeding to birds significantly increased the intestinal villi length, increase in the intestinal villi length could be attributed to the turmeric effect on gut health by reducing intestinal pH, bacterial load and selectively increasing *Lactobacillus* count. Antioxidants present in turmeric powder may effectively scavenge the generated free radicals caused by stress, consequently resulting in improved ileal morphology. Thinner intestinal epithelium enhances nutrient absorption and reduces the metabolic demands of the gastrointestinal system. Thinning of the gastrointestinal walls tract may be due to the inhibition of the microbial production of polyamines and volatile fatty acids, known to increase enterocyte turnover rate and activity. This increased net energy committed to maintaining the luminal tissue comes at the expense of more productive purposes such as muscle accretion. Turmeric could control and limit the growth and colonization of numerous pathogenic and non-pathogenic species of bacteria in the bird's gut resulting in balanced gut microbial ecosystems that lead to better feed utilization reflected by improved feed conversion ratio. Turmeric powder modulates the gene expression system of TLRs showing its immune-modulating properties.

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