Mushroom Supplementation in Promoting Health and Performance of Poultry: Review

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Abstract:
This review paper aims to update and discuss the latest data available with respect to the effects of mushrooms in promoting the health and performance of broiler and layer chickens. Most studies proved that different preparations of mushrooms from diverse mushroom species improved feed utilization efficiency, growth rate, egg production, and quality traits. Mushroom supplementation decreased the count of pathogenic bacteria (Clostridium spp., Coliforms, and E.coli) and increased that of beneficial ones (Lactobacillus spp. and Bifidobacterium) in both broiler and layer chickens. Inclusion of different preparations (powders, extracts, leftovers, etc.) of mushrooms resulted in lower cholesterol and other lipid metabolites in poultry meat and eggs. Some studies reported no significant effect of mushroom on the performance of broiler and layer chickens, however, it is concluded that mushrooms, in various forms, could be included in poultry diets without any harmful effect on their health. Further research works are also suggested to investigate the opportunities for making mushrooms part of the compound poultry feed ingredients in countries like Ethiopia.

Keywords: Broiler, Feed additives, Layers, Mushrooms, Poultry, Chickens.

1. INTRODUCTION
Feed constitutes the major input that decides the profit margin in the poultry industry [1 - 3]. In economic terms, feed cost accounts for 60-75% of the total cost of poultry production [4]. The poultry industry is also under increasing pressure to produce good quality and high quantitative products for consumers [5]. Therefore, there is a need for new intensive techniques to allow efficiency and augment poultry productivity. In this view, feed additives (antibiotics, probiotics, organic acids, essential oils, prebiotics, enzymes, etc.) help in improving the efficiency of feed utilization and thus reducing the high cost of feed [6].

The use of antibiotics in poultry feed as a growth promoter has been beneficial in the improvement of production parameters and disease prevention [7]. However, the continuous and over application of in-feed antibiotics in poultry production has created public and animal health hazards because of concern over the development of antibiotic resistant bacteria [8 - 11]. Removal of antibiotics as growth promoters has then led to animal performance problems, feed conversion ratio, incensement, and a rise in the incidence of certain animal diseases [12]. Consequence, there has been a growing interest in finding viable phytopgenic or plant-derived replacements of antibiotics in poultry feed for production enhancement and disease prevention [13, 14]. Natural materials have been considered as safe feed additives to improve the efficiency of feed utilization and growth performance of poultry [15 - 17]. Recently, mushrooms have been investigated as safe alternative natural products to be included in poultry diets [18].

Traditionally, mushrooms have been grown for human food as well as pharmacological purposes in different countries [19]. Medicinal mushrooms are an increasing focus of research due to their capacity to exert growth-promoting, antioxidant, immunostimulatory, antimicrobial, anti-inflammatory, hypocholesterolemic and probiotic activity [20, 21]; thus can be used effectively as an alternative to antibiotic growth promoters for poultry [22]. Although the mushroom has long been cultivated and utilized in different parts of the globe, there has been poor consumption habits in Ethiopia. In recent years, there has been a growing demand for mushrooms by consumers, particularly in urban areas of the country [23], and more people started involving in mushroom cultivation business. Nevertheless, incorporating mushrooms in a commercial poultry diets has not received much attention in Ethiopia in particular and Africa in general. It also was reported that in spite of the medicinal and nutritional values of...
different edible mushrooms, utilization is limited for animal production globally [24]. Studies have been conducted to evaluate the effect of including various mushroom preparations (extracts, powders, leftovers, etc.) in poultry diets. The objective of this review was, therefore, to update and discuss the latest scientific information available with respect to some medicinal mushrooms such as Flammulina velutipes, Pleurotus ostreatus, Lentinus edodes and Agaricus bisporus proven to be effective in promoting the health and performance of broiler and layer chickens.

2. METHODOLOGY

This review paper attempted to collect and synthesize information from different source materials, mainly journals, from previous research works on the effects of common mushrooms on the health and performance of both broiler and layer chickens.

3. REVIEW

3.1. Nutrient Composition and Functional Components of Mushrooms

The constituents of commonly used mushrooms in the poultry rations are presented in Table 1. The highest crude protein (23.0%) and the lowest crude fiber (7.8%) have been reported in the fermented mycelium of Flammulina velutipes mushroom, followed by Pleurotus ostreatus powder. In another study conducted to evaluate the constituents of nine mushroom species, the crude protein content ranged from 16.47% in P. eryngii to 36.96% in P. ostreatus (black oyster) [25]. The presence of higher crude protein content in Flammulina velutipes mushrooms suggests its potential to be used as a protein source feed ingredient. Most of the mushroom preparations had CP content higher than maize grain (8.5%) [26], which is the most commonly used conventional feed ingredient in poultry rations. The value for crude fiber was higher in the stalk part of Flammulina velutipes (Table 1). Some findings have also shown high levels of dietary fibre (24.47–46.62%) [25]. With respect to energy content, mushrooms have been reported to be low calorific values [27]. The ether extract value ranged from 1.5 percent in the stalk waste of Flammulina velutipes to 3.8 percent in the waster medium of Cordyceps militaris mushroom. The variability in the nutrient composition could be attributed to the differences in strain, substrate development stage [28], climatic condition, and part of the mushroom used. Vargas-Sánchez et al. [29] reported about 3.9 and 7.9 g kg$^{-1}$ of lysine and methionine, respectively, in Pleurotus ostreatus mushroom powder. Eun-Ju et al. [30] have reported about 4.1, 5.1 and 0.3 g kg$^{-1}$ of lysine, cysteine and methionine in ethanolic extracted Lentinula edodes mushrooms, respectively. Consumption of mushrooms helps in obtaining all amino acids considered to be essential for simple stomached animals’ nutrition like chickens [25]. Pathania et al. [31] reported that mushrooms are also rich in vitamin B12 and folic acid, which are uncommon in vegetables.

In addition to the proximate constituents of mushrooms, different functional or active components are found in mushrooms fruiting bodies and mycelium [35]. The major functional components of mushrooms with their mode of action on broiler and layer chickens are summarized in Table 2. The beta-glucan is the main polysaccharide and bioactive component in medicinal mushrooms. It is recognized as potent immunological stimulators in animal cells, and the contents of β-glucan ranged from 1.58 to 16.91 mg g$^{-1}$ of dry matter among the nine edible mushrooms [25]. It has also been reported that different medicinal mushrooms are rich in phenolic compounds, especially phenolic acid, which is the major naturally occurring antioxidant component found in mushrooms to help improve the antioxidant status of chickens [36].

Table 1. Chemical composition (%DM) of some mushroom species used in different experiments on broiler and layer chickens.

<table>
<thead>
<tr>
<th>Species</th>
<th>Part Used</th>
<th>Chemical Composition</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flammulina velutipes</td>
<td>Stalk waste</td>
<td>DM: 85.3 CP: 12.8 EE: 1.5 CF: 20.2 Ash: 8.4 ME: 15.2</td>
<td>[19]</td>
</tr>
<tr>
<td>Flammulina velutipes</td>
<td>Fermented mycelium</td>
<td>DM: 89.5 CP: 23.0 EE: 2.6 CF: 7.8 Ash: 6.8 ME: ND</td>
<td>[33]</td>
</tr>
<tr>
<td>Pleurotus ostreatus</td>
<td>Vegetative Mature P. ostreatus</td>
<td>DM: 16.6 CP: 22.6 EE: 5.0 CF: 16.3 Ash: 8.2 ME: ND</td>
<td>[34]</td>
</tr>
</tbody>
</table>

Abbreviations: CF=crude fiber; CP=crude protein; DM=dry matter; EE=ether extract; ME=metabolizable energy; ND=not determined

Table 2. Some functional components of mushrooms with their mode of actions and roles on broiler and layer chickens.

<table>
<thead>
<tr>
<th>Functional Components</th>
<th>Mode of Actions and Roles</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polysaccharides such as β-glucans and mannans</td>
<td>Increasing immune response by improving the growth of beneficial microbial population(lactobacilli) and inhibiting harmful biota of gastrointestinal tract, and hence; improving digestibility, feed conversion ratio and performances</td>
<td>[19,25,37,38]</td>
</tr>
<tr>
<td></td>
<td>Resistant to birds’ digestive enzymes, aiding in the increase of faeces volume and intestinal mobility. Lowering cholesterol through reducing the absorption or increasing excreta</td>
<td></td>
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</table>
3.2. Effects on Gut Health and Immunity

Experiments using different types and forms of mushrooms on gut health and immunity of broiler and layer chickens produced promising results. Mahfuz et al. [24] reported that winter *Flammulina velutipes* (Fig. 1) stalk helps to control pathogenic bacteria as well as increased beneficial bacteria in the cecum to keep sound gut health in layer chickens. Willis et al. [41] have shown that broiler chickens receiving *Lentinula edodes* extract had a significant increase in the population of bifidobacteria in the fecal samples than the control (no additive). Similarly, dietary spent mushroom (*Cordyceps militaris*) substrate resulted in significantly higher numbers of lactobacillus spp., and *Bifidobacterium* in the cecum and decreased numbers of *Clostridium spp.*, *Coliforms*, and *E.coli* compared to the control group [42]. Supplementation of broiler chicken’s diets with Reishi, *Ganoderma lucidum*, Fungus Myceliated Grain (FMG) in the cecal and decreased numbers of *Clostridium spp.*, *Coliforms*, and *E.coli* compared to the control group [42]. Supplementation of broiler chicken’s diets with Reishi, *Ganoderma lucidum*, Fungus Myceliated Grain (FMG) in the cecal and decreased numbers of *Clostridium spp.*, *Coliforms*, and *E.coli* compared to the control group [42]. Supplementation of broiler chicken’s diets with Reishi, *Ganoderma lucidum*, Fungus Myceliated Grain (FMG) in the cecal and decreased numbers of *Clostridium spp.*, *Coliforms*, and *E.coli* compared to the control group [42].

Results from Mahfuz et al. [24] suggested that supplementation of *Flammulina velutipes* mushrooms (3-5%) in laying hens' diet decreased the count of pathogenic bacteria (*Clostridium spp.*, *Coliforms*, and *E.coli* and increased that of beneficial ones (*Lactobacillus spp.* and *Bifidobacterium*). These strong antimicrobial effects of mushrooms might be due to the ability to change cell membranes and cause ion leakage, thus making microbes less virulent [44]. In another study, Mahfuz et al. [19] demonstrated that feeding *F. velutipes* mushroom stalk waste at 2% level can be an effective way of improving the immunity in broilers. It has also been demonstrated that broilers experimentally challenged with *Eimeria* were more responsive to treatment with mushroom FMG than those who obtained a natural infection [45]. A trial conducted [46] using *Eimeria*-infected chickens showed that mushroom extract-fed group showed a significant development of gastrointestinal tract (GIT) compared with the non-fed group. Polysaccharides from medicinal mushrooms generally do have bioactive effects, and hence, these polysaccharide extracts might increase the activity of intestinal microflora and fermentation end-products such as volatile fatty acids (VFA) and increased proliferation of GIT [38]. According to Muthusamy et al. [47], the polysaccharides, especially β-glucan substances, extracted from mushrooms had significant immune stimulatory functions in broiler chickens. A significant higher antibody response against Newcastle disease and infectious bursal disease was noted in *Flammulina velutipes* mushroom stalk waste fed broiler chickens and concluded that feeding. *Velutipes* stalk waste at a 2% level can be an effective way of improving the immunity in broilers Mahfuz et al. [19].

According to Abou-Zeid et al. [18], *Pleurotus ostreatus* mushrooms could be safely used in broiler feeding as natural feed additives at 2 g kg\(^{-1}\) diet with superior effects on their immune response.
3.3. Effects on Broiler Performance

Most findings highlighted the positive growth performances of broilers supplemented with various forms of mushrooms. Polysaccharide extracts of two mushrooms (Lentinus edodes and Tremella fuciformis) inclusion prompted the growth performance, feed intake and feed conversion ratio of broiler chickens compared to the control group, but were not significantly different from those fed with antibiotic treatment group (20 mg kg\(^{-1}\), virginiamycin (VRG) \([38]\). Giannenas et al. \([37]\) have also found increased performance of broiler chickens fed with 10 and 20 g kg\(^{-1}\) of an edible Agaricus bisporus. In a study with Japanese quails, Asadi-Dizaji et al. \([32]\) found that supplementation with mushroom (Agaricus bisporus) at 2% significantly increased \((p<0.05)\) weight gain and feed intake compared to the control. The possible mechanisms regarding mushrooms include changes in the intestinal microbiota, increased nutrient digestibility, increased feed intake and absorption, enhanced nitrogen absorption, improved immune response, and antioxidant activity \([48]\). In another study conducted to evaluate the feeding of four medicinal mushrooms via fungus myceliated grain (FMG), reduced performance was observed in broiler chickens fed Reishi (Ganoderma lucidum) and Oyster (Pleurotus ostreatus) FMG supplemented diets compared with those fed diets supplemented with Lentinus edodes FMG \([20]\). Dietary inclusion of five levels (0, 0.5, 1.0, 1.5, and 2.0 g kg\(^{-1}\) of diet) of edible mushroom powder (Agaricus bisporus) positively affected broiler weight gain and feed conversion ratio \([49]\). According to Abou-Zeid et al. \([18]\), Pleurotus ostreatus mushrooms could be safely used in broiler feeding as natural feed additives at 2 g kg\(^{-1}\) diet with superior effects on their productive performance.

An increase in daily body weight gain of broilers fed with Agaricus bisporus mushroom was also noted by Guimaraes et al. \([50]\). Daneshmand et al. \([51]\) however found negative effects following administration of oyster mushroom powder (2 g kg\(^{-1}\)) in male broiler chickens. It has also been documented that dried P. ostreatus (oyster mushroom) waste at 1% negatively affected body weight gain and feed conversion ratio of broiler chickens should be added (2 g additive for broiler chickens, which might be due to the high fibre contents in the mushroom additive) \([52]\). Replacement of Pleurotus ostreatus-colonized substrate in standard diet (100-200g kg\(^{-1}\)) of broiler chickens has been found to be effective for improving body weight, feed intake and feed conversion ratio \([53]\). It has been reported that the improved growth and feed utilization efficiency of birds supplemented with natural materials is due to their appetite and digestion stimulating properties \([54, 56]\). No significant differences were observed in daily body weight gain, feed intake, and feed conversion ratio when F. velutipes mushroom stalk waste was incorporated at 1 and 2% in broiler rations \([19]\). In another experiment, Agaricus bisporus mushroom powder and flavophospholipol inclusion, as individual factors, produced positive effect on weight gain and feed conversion ratio of broiler chickens \([50]\). The observed variation between results on broilers growth performance could be attributed to the difference in the type of mushroom species used, forms offered (powder, extracts, leftover, etc.), supplement dose, and may partly be due to the difference in the type of broiler breeds under investigation.

3.4. Effects on Laying Performance and Egg Quality Traits

Unlike broiler chickens, studies are limited regarding the effects of feeding different forms of mushrooms on laying performance and egg quality parameters. Hwang et al. \([57]\) reported that dietary supplementation with shiitake (Lentinula edodes) mushroom powder up to 0.5% positively affects egg production, egg quality, and fatty acid composition of eggs. It was observed that feeding F. velutipes mycelium had no adverse effects on egg production percentage, feed intake, and feed conversion ratio in laying hens, but the egg weight was found greater \((p < 0.05)\) in the 1% and 3% mushroom-fed groups than the control diets \([32]\).

Recently, Karaalp et al. \([22]\) evaluated the effects of supplementing apple cider vinegar (ACV) and feed mushroom (Agaricus bisporus) stalk separately and in combination on performance and certain egg characteristics. Their study found a lack of significant effect of dietary treatments on any performance criteria, and physical external and external egg quality characteristics. Another study by Yoshida et al. \([58]\) demonstrated that supplementation of fermented mushroom bed (Flammulina velutipes) in a laying hen diet (3%) improved egg production and decreased damaged eggs due to broken/soft shells by one-sixth than the control group, which might be associated with the potentials of mushroom in reducing stress conditions. Hens fed dietary spent mushroom (Cordyceps militaris) substrate had higher egg weight and feed conversion ratio than non-supplemented group \((p<0.05)\), but hen-day egg production and feed intake were not affected by treatment groups \([42, 59]\). Kim et al. \([60]\) also reported a lack of difference in egg production, egg mass, egg weight, feed conversion ratio, feed intake, and most internal and external egg quality parameters, but significantly heavy egg yolks were reported for laying hens fed fermented spent mushroom (Hypsipylus marmoreus) substrate in corn-soy based experimental diet. It has also been observed that the inclusion of the dried edible portions of the fruiting body of Cordyceps militaris mushrooms could be employed as a new feed additive that offers potential benefits for elevating egg mass and producing lower cholesterol eggs \([39]\). The improvement in egg production parameters with phytolegic feed additives may be due to the provision of certain functional compounds that improve digestion and absorption of nutrients in the digestive tract \([61]\).

3.5. Effects on Blood Biochemistry

Blood biochemical parameters reflect the health \([61]\) of an animal and are vital indicators of the physiological and nutritional status of an organism as well as the quality of feed \([62]\). Dietary supplementation of Flammulina velutipes stalk waste at 1 and 2% level of inclusion resulted in significantly lower total cholesterol and high density lipoprotein cholesterol than the control diets \([19]\). The cholesterol concentration of egg yolk significantly decreased in egg laying chickens supplemented with shiitake (0.5%) compared to the control group (basal diet with no shiitake mushroom) \([32]\). Conversely, Mužič et al. \([63]\) reported no effect of Shiitake (Lentinus
edodes) mushroom on the cholesterol content of egg yolk. Daneshmand et al. [52] found that inclusion of 2 g kg \(^{-1}\) oyster mushroom power significantly reduced the high density lipoprotein concentration than the probiotic treatments in the 42 days intervention time, whereas this level of inclusion did not bring significant change in the other lipid parameters when compared to the control and probiotic treatments. In hens, dietary spent mushroom supplementation decreased total cholesterol, LDL-cholesterol, and triglycerides (P<0.05) in laying hens [59]. Shah et al. [64] reported the anti-cholesterol property of mushrooms. Other studies also proved that phytochemical feed additives such as garlic, fenugreek, coriander, and garden cress are effective in lowering cholesterol concentration in broiler and layer chickens [65 - 68]. Ming-Yei et al. [69] indicated that both enoki mushrooms (Flammulina velutipes) extract and powder, at 3% level of inclusion, are capable of reducing the level of total cholesterol, triglycerides, low-density lipoprotein cholesterol and high density lipoprotein cholesterol in the serum and liver of the hamsters. In the layer rations, supplementation of Pleurotus eryngii mushrooms resulted in significantly low serum triglycerides and serum cholesterol as compared to the control fed group [33]. Schneider et al. [70] observed that groups that received oyster mushroom soup showed a significant reduction in triacylglycerol concentrations and oxidized low density lipoprotein levels in humans. Addition of edible mushroom (Agaricus bisporus) powder showed an overall decrease in blood lipid metabolite profiles of broiler chickens fed for a period of 42 days [50]. Sogunle et al. [27] also suggested that the administration of oyster mushroom in water and feed at 15 ml/liter and 750 ppm, respectively, could be adopted in cockerel chickens’ for a number of benefits. The same authors further suggested that through proper storage and use as feed some of the larger fungi species, such as Pleurotus ostreatus, can be incorporated into poultry feeds for the mitigation of mycotoxin contamination in the mushroom part of the compound poultry feed ingredients.

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**CONFLICT OF INTEREST**

The authors declare no conflict of interest financial or otherwise.

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