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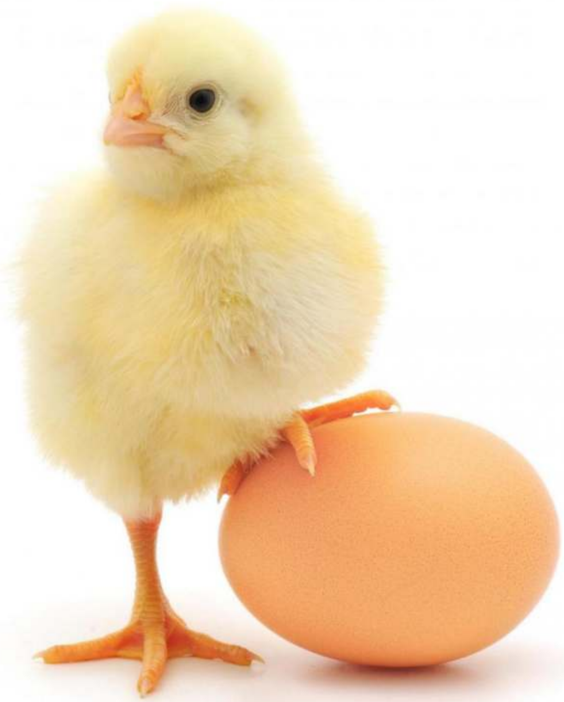

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Review Article
Inclusion of Probiotic on Chicken Performance and Immunity: A Review

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Abstract
Supplementation of probiotic as a mean to improve the health and performance of poultry has generated significant interest over the last few years. A driving force for the interest of probiotic is to eliminate the use of low-dose antibiotics in poultry production. The extensive use of antibiotics in poultry with the purpose of promoting growth rate, increasing feed conversion efficiency and for the prevention of intestinal infections have led to an imbalance of the beneficial intestinal flora and the appearance of resistant bacteria. With increasing concerns about antibiotic resistance, there is increasing interest in finding alternatives to antibiotics for poultry production. To avoid the health hazards of antimicrobials drugs like antibiotics to human as well as poultry, probiotic has been used for as an potential substitute for antibiotics and been proved to be saved in poultry production system. This increased attention toward probiotic supplementation has generated an extensive body of research in the present day. However, there is still a lot of debate in scientific literature regarding the significant effect of probiotic on immune response against specific pathogens and growth performance in poultry. Taking into account the experimental immune responses and performance, this review provides a summary of the use of probiotic for prevention of infectious diseases in poultry, as well as demonstrating the potential role of probiotic in the growth performance and immune response of poultry, with a critical evaluation of results obtained to date. Collectively this study found a strong evidence to suggest that probiotic supplementation may have an impact on the immune response, overall health and performance of poultry.

Key words: Gut health, immune response, performance, poultry, probiotic

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INTRODUCTION

During the last several decades, antibiotics have been widely used in the poultry industry to promote growth. Moreover, the extensive use of antibiotics has the possibility to generate antibiotic-resistant bacteria in animal products[1,2]. Usage of antibiotics as an animal growth promoter in animal diets have been banned or limited in many countries[3,4]. The great challenge of commercial poultry production is the availability of good quality feed with minimum cost on sustainable basis. Feed is the major component of the total cost of production in the poultry industry[5]. Commercial poultry production ranks among the highest source of animal protein and the increase in the size of the poultry industry has been faster than other food-producing animal industries[5,6]. With the current advent of excluding antibiotic growth promoters in poultry production in Europe and America, the issue of controlling enteric infections caused by pathogenic bacteria without the use of antibiotics becomes challenging[5]. Mortality caused by infection is a big problem in the poultry industry. Such infections are responsible for reduced growth rates and consequent economic losses in poultry. Antibiotics are the main tools utilized to prevent or treat such infections in poultry house. Besides, antibiotics are also added to the feed as growth promoters and to accelerate the growth of healthy animals. Unfortunately, the long term and extensive use of antibiotics for veterinary purpose may eventually result in selection for the survival of resistant bacteria species or strain[5,7]. In view of rising concerns on the extensive loss in poultry due to gastro-intestinal problems in chick gut and implementation of strict laws to use of harmful synthetic drug or antibiotics, creates demand of an alternative disease control resources to enhance gut health and to reduce the use of AGPs[8]. The utility of antimicrobial agents as a preventive measure has been questioned, given extensive documentation of the evolution of antimicrobial resistance among pathogenic bacteria and the concern about the side-effects of their use as therapeutic agents has produced a climate in which both consumer and manufacturer are looking for alternatives[9]. Probiotic are being considered to fill this gap and has been used as potential substitute for antibiotics in poultry[1,3,10].

This review is aimed at highlighting probiotic as substitute for antibiotics that can enhance performance, modulating gut microflora and generate immunity which protect the chickens from microbial infections.

Typical example of probiotic: Probiotic are live microbial food/feed ingredients that have a beneficial effect on health that stimulates the growth of beneficial microorganisms and reduces the amount of pathogens, thus improving the intestinal microbial balance of the host and lowering the risk of gastro-intestinal diseases[11]. Probiotics are defined as the culture of live microorganisms which when applied to animals, beneficially affect the host by improving the properties of the indigenous micro-biota. Probiotics are mono-or mixed culture of living microorganisms, which induce beneficial effect on the host by improving the properties of the indigenous microflora[1]. Killed bacterial cultures as well as bacterial metabolites have been included in the definition of probiotic[3,5,12]. Poultry feeds containing probiotic microbes are increasing being considered as feed supplement in poultry diets. Bacteria are the most commonly used as probiotic than fungi. Two genera of bacteria are frequently reported including lactic acid bacteria of the genus *Lactobacllus*[12-18] and *Bifidobacterium*[2,19]. Other bacteria that have been reportedly used, though to a lesser extent in poultry and animal probiotics include *Bacillus*, *Enterococcus*, *Streptococcus*, *Lactococcus*, *Pediococcus*, *Saccharomyces cerevisiae* and *Toulopsis sphaerica* etc.[12,13,20]. Besides, different medicinal fungi including mushroom and yeast have been used as a potential probiotic in farm animals including poultry[21-25]. The mode of action of probiotic includes; competitive exclusion[1], microbial antagonism[12,26-28] and immune modulation[3,12].

Effects of probiotics on growth performance and feed consumption efficiency: Inclusion of a *Bacillus* base direct-fed microbial could improve body weight, body weight gain and feed consumption in broiler when compared to the control group[12,20]. *Bacillus amyloliquefaciens*-based direct-fed microbials (DFM) showed better body weight gain, feed consumption and improved apparent digestibility of dry matter (DM), crude protein (CP) and gross energy (GE) efficiency than that of control and could be an alternative to the antibiotic growth promoter in broilers diets[29]. This study further showed that *Bacillus amyloliquefaciens*-based DFM improved gut structure and resulted in a greater absorption surface, as indicated by improved villus height and villus height to crypt depth ratio in the different small intestinal segments compared to the antibiotic growth promoter-free control diet. In addition, Jayaraman *et al*.[30] reported that the inclusion of *Bacillus subtilis* in broiler diets led to better villus height and villus height to crypt depth ratio associated with better nutrient absorption. Dietary supplementation with probiotic containing *Enterococcus faecium* was reported as increased nutrient retention and reduction in nutrient excretion, leading to improved nutrient digestibility and reduced excreta ammonia emission in laying hen[26]. Broilers chickens fed with *Bacillus subtilis*, had greater body weight gain (BWG) than those fed with the control diet was reported by Hosseindoust *et al*.[31]. Dietary direct-fed microbials (DFM) supplementation as probiotic that contained a mixture of *Lactobacillus reuteri*, *Bacillus subtilis* and *Saccharomyces cerevisiae* significantly increased the body weight gain of broilers during 0-21 days. The feed intake was reduced, whereas the feed conversion was improved significantly when birds were fed DFM at 0-7 days of age[32]. Dietary probiotic significantly enhanced the feed intake and weight gain in starter phase only was reported by Cengiz *et al*.[33]. Increased in feed intake and water consumption is recorded in laying hens fed with liquid probiotic mixed culture (LPMC) containing two type microorganisms, *Lactobacillus* and *Bacillus* species[34]. Zhang and Kim[27] reported an increase body weight and FI in chicken fed with multistrain probiotic compared with that in control group fed basal diet. Significant increase in body weight gain in broilers fed with probiotic *Lactobacillus*, *Bifidobacterium*, *Coliforms* and *Clostridium* sp. was reported by Song *et al*.[35]. Abdel-Raheem *et al*.[36] reported that significantly higher body weight is recorded on broiler flocks that received probiotic. Mansoub[37] reported significant increase in body weight of broilers fed with *Lactobacillus acidophilus* and *Lactobacillus casei*. Probiotic (*Saccharomyces cervisiae*) supplementation of broilers, at level of 1, 1.5 and 2% had significantly increased the body weight gain, feed consumption and feed conversion efficiency[38]. In some studies, dietary *Bacillus*-based direct-fed microbials are reported to have beneficial effects on animal and poultry growth and feed conversion efficiency[26-27,39].

In contrast dietary probiotic had no significant effect on live body weight, feed consumption and feed conversion ratio[40]. Injection of probiotic bacteria especially *B. subtilis* into the amniotic fluid has no effect on growth performance in broiler chickens[41]. Jerzsele *et al*.[42] reported no effect of direct fed microbes as probiotic on the performance of broilers. Results from a study by Babazadeh *et al*.[43] indicated that probiotic did not have any significant positive effect on feed intake, body weight and feed conversion ratio (FCR) in broiler. Hassanein and Soliman[44] reported FI values of different treated groups were approximately similar and lacked significance with layer flock that fed with *Saccharomyces cerevisiae*. Ramasamy *et al*.[45] reported that supplementation of probiotic *Lactobacillus* cultures did not influence the feed intake, egg production or egg mass of hens throughout the 48 weeks period. Feed consumption and body weight gain was not affected by the dietary probiotic supplementation[37,46-48].

Effects of probiotics on egg production and quality: Park *et al*.[49] reported that pro-biotic (*Enterococcus faecium* DSM 7134) supplementation resulted in a significant increase in egg production, egg shell thickness and nutrient digestibility (dry matter, nitrogen and energy) in laying hens. Highest hen day production and egg weight in layers supplemented with probiotics mixed culture containing two type of microorganisms, *Lactobacillus* and *Bacillus* species was reported by Pambuka *et al*.[34]. Tang *et al*.[50] reported that laying hens fed with probiotics significantly improved egg yolk total unsaturated fatty acids, total omega 6 and polyunsaturated fatty acids (PUFA), including linoleic and alpha-linolenic acid as well as significantly decreased egg yolk cholesterol, total saturated fatty acids when compared with control. The improvements in the levels of essential fatty acids (EFA) (linoleic acid and alpha-linolenic acid) can be increased via supplementation with probiotics Yi *et al*.[51]. In a subsequent study, Abdelqader *et al*.[52] determined the efficacy of the dietary inclusion of *Bacillus subtilis* and inulin, individually or in combination. The results showed a beneficial effect of diet supplementation with probiotic (0.10%), inulin (0.10%) or symbiotic on egg performance, eggshell quality and calcium retention in aged hens. Dietary *Pediococcus acidilactici* as probiotic supplementation did not significantly affect the body weight, feed intake and egg production of hens but increased egg weight, eggshell thickness, eggshell relative weight and egg specific gravity and it improved feed efficiency ratio per kilogram of eggs[53]. In addition, Hassanein and Soliman[44] indicated that significant higher egg production was recorded in Hyline layers supplemented with probiotic *Saccharomyces cerevisiae*. Besides, in some studies, laying hens fed with the probiotic found greater egg production, egg weight and higher eggshell thickness than hens fed the diets without the probiotic[48,54-56].

In contrast dietary probiotic had no significant effect on egg production and egg mass but significant effect was recorded on egg weight[57-58]. No significant improvement in egg production and egg weigh of hens supplemented with probiotic contains *Lactobacillus acidophilus*[45,59]. The positive effect of probiotics on eggshell quality parameters was not observed in laying hens fed diets supplemented with yeast cell wall[60]. Albumen quality is often measured primarily to judge the freshness of egg. Haugh unit is the most commonly used unit for measuring albumen quality of eggs. No significant effect with probiotic supplementation in laying hens on Haugh unit was reported by Tang *et al*.[61] and Mohebbifar *et al*.[62]. In addition, several studies with layers failed to confirm the positive effects of dietary probiotic on eggshell quality and yolk color[51,61,63,64].

Effect of probiotic on chicken gut microflora: Chen *et al*.[65] reported that probiotic which contain *Lactobacillus* culture can control the pathogens population and alter gastrointestinal flora. In another recent study by Majidi-Mosleh *et al*.[41] stated that injection of probiotic bacteria especially *B. subtilis* into the amniotic fluid has a beneficial effect on ileal MUC2 gene expression and bacteria population during the 1st week post-hatch in broiler chicken. The result showed that probiotic strains decreased significantly the *Escherichia coli* population and increased the lactic acid bacteria population during the 1st week of post-hatch. Park *et al*.[49] reported that probiotic (*Enterococcus faecium* DSM 7134) supplementation resulted in a significant reduction in fecal coliform counts as compared with control. Lei *et al*.[29] found that dietary inclusion of direct-fed microbials (DFM) decreased the *Escherichia coli* population in cecum at day 21 and 42 along with the population of *Lactobacillus* was increased in DFM groups as compared with control and antibiotic groups. Latorre *et al*.[66] reported that chickens fed on the *Bacillus*-DFM diet showed a significant reduction in the number of Gram-negative and anaerobic bacteria in the duodenal content compared to control. The population of *Lactobacillus* spp. in gizzard was significantly higher in the probiotic diet contain *Bacillius subtilis* compared with control[31]. Salim *et al*.[32] stated that the dietary supplementation of DFM decreases the number of *E. coli* and improves the ileal morphology of broiler chickens. Dietary supplementation of the probiotic increased excreta *Lactobacillus* counts and decreased *Escherichia coli* counts compared with hens fed the diets without the probiotic[54]. Probiotic (*Bacillus subtilis* C-3102) significantly increased *Lactobacillus* counts in the cecum, ileal and excreta, as well as reduced *Escherichia coli* counts in the cecum and excreta, compared with control. In addition, supplementation of probiotic also tended to reduce *Clostridium perfringens* counts in the large intestine and excreta, while linearly reducing *Salmonella* counts in the cecum, ileal, large intestine and excreta, compared with control[20]. Lourenco *et al*.[67] indicated that feeding *Bacillus subtilis* decreased significantly the *Salmonella* population in the broiler gut. Digestive tract of chickens is free of microorganism before hatch; early placement of beneficial bacteria in the gut can prepare suitable conditions for establishing a normal microflora and improve quality and health of the gut[5,41]. Lee *et al*.[13] stated that it takes 2-4 weeks for a stable microbial consortium in the gut of chickens. During this period of microbial colonization of the chicken gastro-intestinal tract (GIT), the chicks are exposed to the risk of being colonized by pathogenic organism when their immunity is low. Pathogenic microorganism commonly associated with poultry diseases causing economic losses are the protozoa *Eimeria* causing *coccidiosis*[25] and the following bacteria *Salmonella*, *E. coli*, *Streptococcus*, *Clostridium perfringens* etc. Microbial infections have resulted in chicks weight loss, death, poor egg and meat production. On the other hand, when GIT of chicken became colonized by beneficial microbes, it influences the absorption of nutrient and vitamins, enhancement of performance, prevention of inflammatory reactions[5,18]. It was shown that addition of probiotic to diet of broiler chickens enhanced nutrient digestibility and improved caecal microflora composition[28]. There are about 10^{-7}-10^{-11} bacteria CFU g^{-1} of gut digest and through molecular studies identified 640 species belonging to 140 genera and the diversity of the microbial flora of chicken GIT depends on several factors including diet composition, age of the chicken, breed, geographic location and the specific section of the GIT such as small intestine, ileum, cecum[5,68]. At maturity, the chicken GIT is quite diverse consisting mostly of bacteria and to a lesser extent protozoa and fungi[69]. Probiotic species belonging to *Lactobacillus*, *Streptococcus*, *Bacillus*, *Bifidobacterium*, *Enterococcus*, *Aspergillus*, *Candida* and *Saccharomyces* have a beneficial effect on modulation the intestinal microflora and pathogen inhibition in broiler[19,29,32,34,65,66,70]. Some studies have also been shown that feeding broilers and layers chicken with fungi myceliated grains have preferentially increased *Bifidobacteria*, while decreasing the population densities of pathogenic *Salmonella* and *Eimeria*[19,25,29,71].

Effect of probiotic on imune response in chicken: One of the most important roles of probiotic microorganism is to stimulate the immunity against invading pathogenic microbes. Different probiotic microorganisms including the normal microflora of the GIT have known to stimulate immunity in the host species. Fathi *et al*.[40] found that dietary probiotic supplementation had a positive effect on serum immunoglobulin M (IgM) and cell-mediated immunity when compared to the control, whereas serum immunoglobulin A (IgA) and immunoglobulin Y (IgY) were improved but not significantly in broiler study. In another recent study in broilers treated with probiotic cultures showed a satisfactory immune response compared with control[72]. Salim *et al*.[32] also reported that direct feed microbes (DFM) as probiotic supplementation could increase the white blood cell and monocyte levels significantly compared with the control in broiler chicken. In addition, feeding DFM significantly increased the plasma immunoglobulin levels when compared with the other treatments. Several authors have been reported the close relationship between the gut microflora and intestinal immune system in chickens and other animals[13,68,69,73]. In a previous study, probiotic supplementation resulted in increases of antibody titres to sheep red blood cells, as well as Newcastle diseases virus (NDV) and infectious Bursal disease virus (IB)[74]. Furthermore, Haghighi *et al.*[75] determined that broiler chickens orally gavaged with probiotics had enhanced production of natural antibodies. The preventive effect of probiotics against *Salmonella* and *coccidiosis* has also been reported by Dalloul *et al.*[76]. Brisbin *et al.*[77] investigated the immune system genes in chicken cecal tonsil and spleen mononuclear cells in response to structural constituents of *L. acidophilus*. Many studies reported the improved immune response against *Eimeria* in chicken fed with mushroom and plant extracts[19,25,78]. The polysaccharides extracted from different mushroom are also known to exhibit immunomodulatory properties[50]. The polysaccharide containing extracellular fractions from oyster mushroom, *Pleurotus ostreatus* was found to stimulate immune system response against microbial infections in vaccinated chickens[79]. Significantly higher antibody production on immune response of broilers was observed by several previous studies[32,80-83].

In contrast, Majidi-Mosleh *et al.*[41] showed that inoculation of probiotic had no significant effect on antibody titres against Newcastle disease virus, antibody titres against sheep red blood cell and cell-mediated immune response of chickens compared to control. In addition, Midilli *et al.*[84] also found the ineffectiveness of probiotic on systemic IgG in broiler.

CONCLUSION

The present review reveals that probiotics could be successfully used as an alternative to conventional antibiotic growth promoter as well as nutritional tools in poultry feeds for promotion of growth, modulation of intestinal microflora and immunomodulation in poultry. In this study we propose to add probiotic in poultry ration as substitute for antibiotics so that it would be a potential strategy for economic poultry production which would be saves for human consumption. This study will help the researcher to uncover the critical areas of probiotic on immunity and gut health, as well as performance that many researchers were not able to explore.

SIGNIFICANT STATEMENT

Despite the wide use of probiotics in poultry ration, future study was suggested by many researchers regarding the role of probiotic on immune response in poultry. This concept is very accurate but should be one major consideration. This future research must use a systematic approach that will investigates the use of probiotic in response to a direct immune challenge and a pathogen challenge, as well as dosages, durations and routes of administration. Once it becomes a comprehensive and consistent evaluation of individual probiotic, it will be able to determine the influence of probiotic as a means to improve poultry performance and health status.

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