Probiotic use in poultry feed: A review

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Abstract

Antibiotic have been in use for a long time in the field of animal production. But the development of antibiotic resistance has led the ground works for the researchers to find alternative to antibiotic use. Also, several countries have imposed strict rules in using antibiotic in animal production. As a result, there is a rising interest in the poultry industry in identifying efficient alternatives for growth promotion and disease prevention. It is considered that antibiotics can be replaced with probiotics as a feed additive. Probiotics are live microbial population used as supplement or feed additives in poultry diet. Commonly known as DFM (direct-fed microbial), they have many beneficial effects on poultry production including improving growth rate, feed intake & feed use efficiency in poultry. They also provide a better GIT health and improve immune function of poultry. Probiotic preparations contain a variety of species i.e., *Lactobacillus bulgaricus*, *L. acidophillus*, *L. casei*, *L. helveticus*, *L. salvarius*, *L. plantarum*, *L. faecalis*, *Streptococcus thermophilus*, *Enterococcus faecium*, *Enterobactris faecalis*, *Bifidobacteria* species, and *Saccharomyces cerevisiae*. To achieve the best results, it is required to choose the right probiotic strains. In this review, the effect of probiotics on growth rate, feed intake, feed conversion efficiency, meat quality, egg production, intestinal morphology and control of enteric pathogens have been discussed. This review also focuses on the mechanisms of action of probiotics.

Keywords: Probiotics, Growth promoters, feed additives, microorganisms, poultry

Chapter 1: Introduction

Poultry is one of the most rapidly increasing segments of the agricultural and veterinary industries. The main goal of this industry, like that of other agricultural sectors, is to achieve maximum production with minimal input. Feed is one of the most significant items of cost in poultry production, accounting for 70% of overall spending in the industry (Jadhav et al., 2015; Khan & Naz, 2013). Poultry producers are losing money as the cost of poultry feed ingredients and compounded feed continues to rise. As a result, the most critical requirement for outstanding germplasm for economic poultry production is balanced and effective feeding.

Several growth promoters such as synthetic hormones and antibiotics have been widely used to boost poultry production, but the development of antibiotic-resistant bacterial strains and the residual effects of these antibiotic in eggs and meat have resulted in a variety of health risks for consumers (Jadhav et al., 2015). Moreover, the use of antimicrobial drugs as a preventive measure has been questioned, given extensive documentation regarding antimicrobial resistance among pathogenic bacteria. As a result, the likelihood of antibiotics being phased out as poultry growth stimulants, as well as concerns about their usage as therapeutic agents, has created an environment in which both consumers and manufacturers are exploring for alternatives (Kabir et al., 2004). Feed additives are being considered to fill this gap and it already produced some significant results in improving animal health and better production.

Feed additives are non-nutritive substances added to the basic feed mix to improve growth or other productive functions, raise feed utilization efficiency, preserve feeds, or benefit animal health or metabolism (Van Saun, 2013). Among the feed additives, the benefit of probiotic use in poultry feed has been well established.

Probiotics are living microorganisms that are used as feed additives or supplements in the diet of animals. Probiotics benefit the host primarily through their activity in the animal's gastrointestinal tract (GIT). Through contributions to gut health and nutrient utilisation, probiotic supplementation in the food can improve animal health and performance (Jadhav et al., 2015).

The objective of this review article was to explore the benefits and usefulness of probiotics in poultry feed along with its limitations, constraints and future prospects. This study is synchronized by combining and updating the results of probiotics use in commercial poultry production, which includes productive performance, meat & egg quality, disease prevention and immunity enhancement.

Chapter 2: Methodology

This review article focuses on the definition, mode of actions, benefits, limitations and future prospects of probiotics in poultry diet. All articles were sourced from databases including Researchgate, Pubmed and Google scholar. Search terms were used in connection with the probiotics were: “probiotics in poultry diet”, “effect of **species** in poultry diet”, “probiotic effect on growth rate of poultry”, “probiotic effect on poultry”, “probiotic effect on egg and meat quality of poultry”, “probiotic effect on immune function of poultry”, “effect of probiotic in the gut of poultry “, etc. A total of 70 articles were selected primarily.

To select articles for further review, inclusion criterion was set; such as the article needs to published after year 2000 and have higher citation comparatively than others. Articles that were previously cited on other review articles were also selected. Articles that have data regarding effect of probiotic on growth rate, feed intake and feed efficiency, meat quality, intestinal histo-morphology, prevention of diseases and egg productions of poultry were selected for review.

After removing duplicates, all titles and abstracts were screened (n = 70) and 35 studies were identified as potentially eligible for the review. Full-text of these 35 articles were sourced and read in full to determine final eligibility. Based on the full-text review, a further 10 articles were excluded. A total of 25 articles met the eligibility criteria and were subsequently included in this review.

Chapter 3: What is Probiotic?

Probiotics are cultures of bacteria (mono or mixed) that affect the features of the host's intestinal microbes and so significantly improve the health and productivity of animals (Jadhav et al., 2015). Probiotics, also known as direct-fed-microbial (DFM), are living microbes that are frequently added to people's meals (Abd El-Hack et al., 2020). They provide beneficial properties to the host, by their primary action in the gastrointestinal tract (GIT) of the animal. Supplementation of different probiotics in the diet of animal can improve health and performance, through contributions to gut health and nutrient use (Neveling & Dicks, 2021). Supplementing farm animals with probiotics, for example, has been linked to immunological modulation, structural modulation, and enhanced cytokine production, all of which help protect the gut mucosa against infections (Bai et al., 2013). The microbial composition of probiotic products ranges from a single strain to multi-strain or species compositions (Kabir et al., 2004).

According to Mahesh et al., (2021) the ideal probiotic for animal feeding should have the following characteristics-

1. Origin from host animal
2. Non-pathogenic
3. Withstand processing and storage conditions
4. Resist both very low pH (gastric acid) and high pH (bile and pancreatic juice of small intestine)
5. Adhere to gastrointestinal tract epithelium or mucus
6. Persist in the intestinal tract
7. Produce various inhibitory compounds (bacteriocin and colicin, etc.)
8. Modulate immune response
9. Able to alter microbial activities

Chapter 4: Common Probiotic Microorganisms

Table 1: Commonly used probiotic microorganisms in poultry feed

Genus	Species	Mode(s) of action	References
Lactobacillus	*L. acidophilus* *L. plantarum* *L. rhamnosus* *L. paracasei;* *L. fermentum;* *L. lactis* *L. reuteri;* *L. johnsonii* *L. brevis;* *L. casei* *L. delbrueckii gasseri*	• Stimulation of adaptive immunity, • Alteration of the caecal microbiome • Production of inhibitory metabolites such as organic acids and bacteriocins	Oelschlaeger, (2010); Perdigon et al., 1995; Tiwari et al., (2012); Bermudez-Brito et al., (2012)
Bifidobacterium	*B. Breve;* *B. infantis;* *B. longum;* *B. bifidum* *B. thermophilum* *B. adolescentis;* *B. animalis;* *B. lactis*	• Competition for colonization sites, competition for nutrients, • Reduction of toxic compounds • Immuno-stimulation	Carey et al., (2008); Giannenas et al., (2012); Patterson & Burkholder, (2003); Tiwari et al., (2012)
Bacillus	*B. coagulans*	• Rapid activation of innate host immune responses • Protection of intestinal barrier function • Production of antimicrobial compounds against Pathogens • Reduction in pathogen colonization • Improvement in feed conversion and greater weight gain	Jayaraman et al., (2013); Abd El-Hack et al., (2020); Bermudez-Brito et al., (2012); Hong et al., (2005)
Enterococcus	*E. faecium*	• Meat quality and antioxidant activity of muscle	Chevalier et al., (2015); Giannenas et al., (2012); Jin et al., (1997)

Saccharomyces	*S. cerevisiae*	• Competitive exclusion of pathogenic bacteria • Production of antimicrobial agents • Balancing the gut microbiome • Stimulation of host adaptive immune system • Improving gut morphological structure	Bai et al., (2013); Tiwari et al., (2012); Oelschlaeger, (2010)

Chapter 5: Modes of action of probiotic

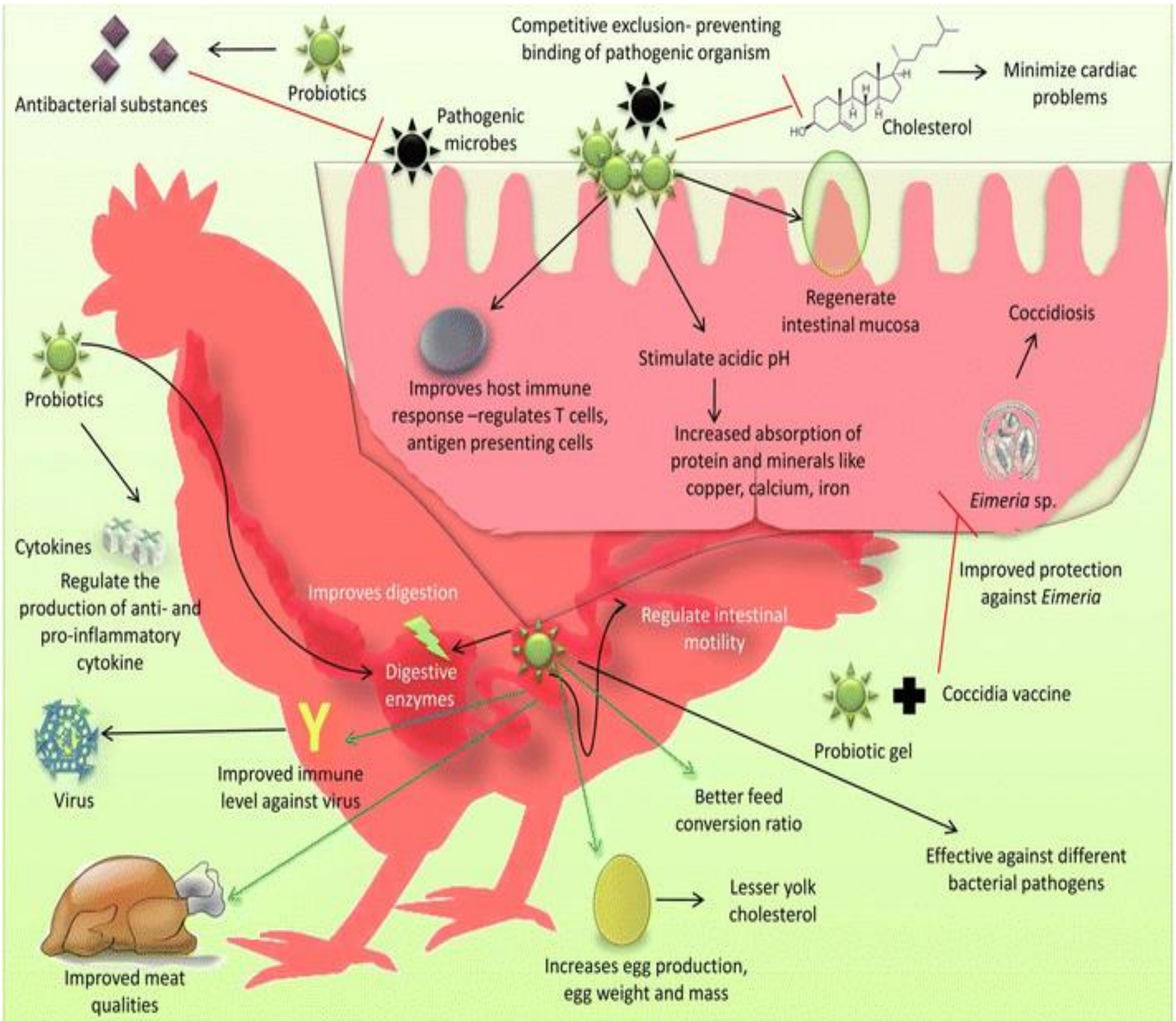
As described by previous studies (Alagawany et al., 2016; Jadhav et al., 2015), probiotics can follow various mechanisms –

1. Inhibition of all pathogen via producing organic acids and antibacterial substances, i.e., hydrogen peroxide, lactocidin, acidophillin, bacteriocins, and defensins (dipicolinic acid and fatty acids) (Tiwari et al., 2012)
2. Blockading of pathogenic bacteria adhesion to intestinal epithelial binding sites using competitive inhibition which is also knows as competitive exclusion (Tiwari et al., 2012)
3. Modulating host immune response by impacting regulatory T cells, antigen presenting cells, effector of T and B cells, and enterocytes (Oelschlaeger, 2010)
4. Regeneration of intestinal mucosa and affecting the digestion by enhancing digestive enzymes secretion and helping in proper digestive process (Perdigon et al., 1995).

Bermudez-Brito et al., (2012) & Jadhav et al., (2015) also described other modes of action. These are –

- Creation of micro ecology hostile to pathogenic microbes by decreasing gut pH with production of lactic acid;
- Offering digestive protein, vitamins, enzymes and other cofactors; and some growth factors (malic acid, some short chain FAs) for proliferation of beneficial bacteria;
- Neutralization of enterotoxins;
- Increasing the area of absorption of small intestine by improving intestinal morphology (increase the villus height, increase goblet cell number, and decrease the crypt depth).

Figure 1: Modes of action and beneficial activities of probiotics in poultry(Alagawany et al., 2016)



Chapter 6: Benefits and use of probiotics in poultry diet

6.1 | Effect on Growth Rate:

Probiotics can improve the growth rates in broiler chicken (Table 2). In many cases the improvement in growth rate of the probiotic treated birds was associated with the increase in feed intake (Lei et al., 2015) and improved feed efficiency (Mountzouris et al., 2010; Shim et al., 2012; Zhang & Kim, 2014).

Improved feed use efficiency is the result of increased digestibility of feed; this could be one of the mechanisms that affect the improved growth rate of poultry. Also, the performance in the probiotic fed birds being higher than non-probiotic fed birds may be due to a change in the microbial populations in the gut containing higher production of SCFA (short-chain fatty acid) and immuno-modulation (Zhao et al., 2013). Increased villus height has also associated with improved growth rate as it increases absorption of nutrients from the intestine.

However, some probiotics failed to improve broiler growth (Hung et al., 2012; Zhao et al., 2013). For example, Cao et al., (2013) reported that male Cobb broilers challenged with *E. coli* feed with *E. faecium* (HJEF005) at 109 cfu/kg of feed showed improve growth rate, while Zhao et al., (2013) used a different strain (LAB 12 – CGMCC 4847) in male Ross broilers and fed at the rate of 2 ×109 cfu/kg of feed, found no growth effect. This difference in these two studies may be due to use of two of different probiotic strains in two different boiler breeds.

Recent studies suggested that, use of probiotics along with probiotics improve the probiotic effect (Mookiah et al., 2014). A prebiotic is a selective fermented ingredient that allows certain changes in the composition and/or activity of the microflora in the intestines, resulting in advantages to the host's well-being and health (Gibson et al., 2004).

An interesting observation from trials feeding probiotic in poultry is that, some probiotic promote growth in the starter (early) phase (Bai et al., 2013) while, other probiotics affect the grower-finisher (later) phase (Abdel-Rahman et al., 2013; Shim et al., 2012). In addition, some research found that broiler growth rates improved throughout the production cycle (Cao et al., 2013; Mookiah et al., 2014; Rahman et al., 2014). The underlying cause for this difference is not known, but this can be related to the dynamics of the gut microbiota. So, different probiotics should be chosen to use in particular growth periods, i.e. choosing the appropriate probiotic for the appropriate time, remains to be determined.

Table 2: Probiotic effects on growth rate of poultry.

Microorganisms	**Growth Rate**			**References**
	Pre-starter – starter phase	**Grower – finisher phase**	**Overall**	
B. subtilis	NS	S(+)	S(+)	Abdel-Rahman et al., (2013)
E. faecium	NS	S(+)	S(+)	Abdel-Rahman et al., (2013)
L. fermentum *S. cerevisiae*	S(+)	NS	–	Bai et al., (2013)
B. coagulans	–	–	S(+)	Zhou et al., (2010)
L. acidophilus; B. subtilis *S. cerevisiae; A. oryzae*	NS	S(+)	S(+)	Shim et al., (2012)
L. reuteri; E. faecium; *Bifidobacterium animalis* *Pediococcus acidilactici* *L. salivarius*	NS	S(+)	S(+)	Mountzouris et al., (2010)
C. butyricum	NS	S(+)	S(+)	Zhou et al., (2010)
L. acidophilus, *B. subtilis DSM 17299,* *C. butyricum*	NS	S(+)	S(+)	Zhang & Kim, (2014)
L. acidophilus; L. casei *E. faecium; B. bifidum*	S(+)	S(+)	S(+)	Landy & Kavyani, (2013)
L. acidophilus; *L. bulgaricus;* *L. plantarum; S. faecium;* *Bi. Bifidus; B. subtilis* *B. licheniformis* *B. megaterum;* *B. mesentricus* *B. polymyxa; S. bourlrdii*	S(+)	S(+)	S(+)	Rahman et al., (2014)
B. amyloliquefaciens	NS	S(+)	S(+)	Lei et al., (2015)

Notes: S(+) = Significantly increased, NS = Not significant, – = Not studied

6.2 | Effect on feed intake and feed efficiency

As feed cause the highest cost in poultry production, little improvements in using feed efficiently have a significant economic impact. In-feed probiotics mainly improve the feed intake and feed efficiency which subsequently improve the performance of poultry (Shim et al., 2012) but the outcome is not always the same. The summary of the results of some studies regarding the performance of FCR in birds feeding different probiotics are shown in Table 3.

Previous study reported that average feed intake and FCR was reduced by 8 and 10%, respectively in broiler fed birds fed diet supplemented with probiotic *B. coagulans* during 22 to 42 days of age (Hung et al., 2012). Similarly, Amerah et al., (2013) reported that that supplementation of *B. subtilis* (strains BS8, 15AP4 and 2084) sourced from a commercial probiotic during grower/finisher phase of a 42-day feeding trial resulted in a reduction in feed intake of 2% along with reduction in FCR of 2.7%. From 1-21 days of age, feed intake also reported to be reduced by 5.6% in birds consumed diet added with *Lactobacillus* strains (Mookiah et al., 2014). However, FCR was increased in both starter (7.3%) and finisher phase (12%).

It has been suggested that feed intake can be improved in birds fed probiotics added diet without any change in the FCR (Afsharmanesh & Sadaghi, 2014). In contrast, probiotics can also improve FCR without significant improvement in feed intake (Mountzouris et al., 2010; Shim et al., 2012; Zhang & Kim, 2014). It can also increase both feed intake and FCR significantly (Landy & Kavyani, 2010).

The effect of probiotics on feed intake and feed use efficiency may vary depending on the growth phase of the birds. Some probiotics had little or no effect on feed intake and FCR during the starter phase, but improved it during the grower-finisher phase, or vice versa (Afsharmanesh & Sadaghi, 2014; Huang et al., 2004; Mookiah et al., 2014).

Table 3: Probiotic effect on feed intake and feed conversion ratio

Microorganisms	Feed Intake	Feed Conversion Ratio			References
		Pre-starter – starter phase	Grower – finisher hase	Overall	
L. fermentum *S. cerevisiae*	S(+)	S(–)	NS	NS	Bai et al., (2013)
B. coagulans	NS	S(–)	S(–)	S(–)	Hung et al., (2012)
L. acidophilus; B. subtilis *S. cerevisiae; A. oryzae*	NS	S(–)	S(–)	S(–)	Shim et al., (2012)
C. butyricum	S(+)	NS	NS	NS	Zhou et al., (2010)
L. acidophilus *L. casei; E. faecium* *Bi. bifidium*	S(+)	S(–)	S(–)	S(–)	Landy & Kavyani, (2013)
B. amyloliquefaciens	S(+)	S(–)	S(–)	S(–)	Lei et al., (2015)

Notes: S(+) = Significantly increased, NS = Not significant, S(–) = Significantly decreased, – = Not studied

6.3 | Effect on Meat Quality

Carcass yield of broiler birds at day 42 was increased concurrently with increased growth rate along with improved feed use efficiency with the use of the commercial probiotic containing *E. faecium* (in drinking water) and a mix of (in feed) the spore-forming bacterium *B. subtilis* and a yeast *S. cerevisiae* (Abdel-Rahman et al., 2013). In contrast, Afsharmanesh & Sadaghi, (2014) found birds at day 42 treated with a commercial probiotic containing *B. subtilis* showed no change in carcass production, growth rate, or feed efficiency.

It has been reported that dietary supplementation of probiotic (*B. coagulans*) increased the meat quality by decreasing the drip loss of poultry meat (Zhou et al.,2010) during pre-freezing and post-freezing storage (Kabir et al., 2004).

A. W. Zhang et al., (2005) conducted an experiment with 240, day-old, male broilers to investigate the effects of *Saccharomyces cerevisiae* cell components on the meat quality. The authors reported that the whole yeast or *Saccharomyces cerevisiae* extract not only improved the meat tenderness but also the growth rate and FCR of birds. Zhao et al., (2013) observed increased fat deposition (3.6%) in Ross broiler birds treated with probiotic *C. butyricum*, while there was no effect found with the probiotic *E. faecium*.

6.4 | Effect on intestinal microbiota & intestinal morphology

The functions and compositions of gut microorganisms are greatly influenced by the in-feed use of different probiotics. Studies suggested different mode of action of probiotic in gut which includes the competition with other micro-organisms for nutrients, binding sites and receptors on intestinal mucosa and also suppressing the growth of other microbes by producing antimicrobial agents (Abd El-Hack et al., 2020). Abd El-Hack et al., (2020) also mentioned other potential mechanisms of probiotics with antagonistic activity against pathogenic bacteria such as immune modulation, organic acid production, lowering gut pH and stimulation of host defense systems. Another study reported that ovo- inoculation of probiotic (*B. bifidum*, *Bifidobacterium longum*, *B. animalis* and *Bifidobacterium infantis*) increased the lactic acid bacteria and *Bifidobacteria population while* decreased the total coliform count (Abdel-Moneim et al., 2020). Another study by Abou-Kassem et al., (2021) reported that dietary supplementation of *Bacillus toyonensis* and *B. bifidum* decreased the caecal coliforms and *E. coli* populations.

The intestinal functionality mainly determined by the structure of the intestinal mucosa which also has significant impact on growth performance of poultry. Generally, an increase in the villus height and villus height:crypt ratio increases the absorption of nutrients due to a larger surface area (Afsharmanesh & Sadaghi, 2014). Mitotic cell division activation and proliferation of gut epithelial cells by probiotics may explain the increase villus length (Abd El-Hack et al., 2020).

The structure of intestinal mucosa, especially the villus height and the villus:crypt ratio in were increased by *B. subtilis* (Afsharmanesh & Sadaghi, 2014), *B. coagulans* (Hung et al., 2012), *L. salivarius*, *P. parvulus* (Abd El-Hack et al., 2020) and *E. faecium* (Abdel-Rahman et al., 2013; Cao et al., 2013). Jayaraman et al., (2013) found that supplementation of *B.*

subtilis PB6 to birds with necrotic enteritis could significantly improve the damaged and distorted intestinal villi caused by *Cl. Perfringens*.

6.5 | Control or prevention of enteric pathogens

Poultry meat has been linked with the transmission of various enteric pathogens. Common enteric pathogens including *Salmonella* and *Campylobacter* spp. are associated with the transmission. This contamination of the poultry meat and products originates primarily from the gastrointestinal tract of poultry, specifically the caeca, which has a high microbial activity.

To produce poultry meat and eggs free from *Salmonella* contamination, recent study has focused on reducing the infection from *Salmonella* through competitive exclusion. Certain strains of *Lactobacillus* spp. has been used to adhere to the intestinal wall of the birds and competitively eject the *Salmonella* from the gut (Khan & Naz, 2013).

Haghighi et al., (2008) claimed that probiotics help reducing *Salmonella* colonization in caeca by several fold depending on probiotic dose. This author suggested that use commercial probiotic products containing L. *acidophilus*, *Bi. bifidum*, and *S. faecalis* at a dose rate of 1×10^5 and 1×10^6cfu could have significantly reduce Salmonella colonization in the intestine. Higher dose rate also resulted in higher reduction in the cecal *Salmonalla* population (Haghighi et al., (2008). Similarly, Willis & Reid, (2008) reported that using a commercial probiotic containing *Lactobacillus*, *Bifidobacterium* and *Enterococcus* has resulted in reduced prevalence of *Campylobacter* infection in broiler chicken.

Jayaraman et al., (2013) found that administration of *B. subtilis* (strain PB6) to broiler chickens infected artificially with *Clostridium perfringens* reduced the intensity of intestinal lesions and also significantly reduced the number of pathogen cells in the GIT.

Supplementation of the probiotics in poultry diet helps in reducing *Escherichia coli* and total coliform counts in the intestine and it also increased the numbers of *Lactobacilli* found in the intestine of broiler chickens (Dibaji et al., 2014). In addition, the probiotic mixture containing *Lactobacillus pentosus* ITA23 and *Lactobacillus acidophilus* ITA44 improved bacterial count of the cecal contents, by decreasing *Escherichia coli* population and increasing beneficial bacteria (Shokryazdan et al., 2016).

Probiotics also helps in reducing parasitic load in the GIT (Khan & Naz, 2013). Giannenas et al., (2012) used probiotics containing *E. faecium, B. animalis, L. reuteri* and *B. subtilis*, either singly or in combination, and found that these products help in reducing coccidiosis in birds. These probiotics were thought to maintain gut health in infected birds, and also reduced oocysts shedding significantly from the infected birds, thereby results in less transmission of disease (Dalloul et al., 2003; Giannenas et al., 2012).

6.6 | Effect on egg production and quality

Probiotics increase egg production, improve egg quality and decrease egg contamination (Kurtoglu et al., 2004). Further, it has been reported that probiotics increase egg shell weight, shell thickness and serum calcium in layers (Panda et al., 2003). There are also variable effects of probiotics supplementation on feed efficiency in laying hens. However, probiotic supplementation consistently reduces the cholesterol content of egg yolk and this finding is consistent over the studies (Table 4). Yolk cholesterol has been reduced by lactic acid bacteria (Panda et al., 2003), Bacillus spores (Kurtoglu et al., 2004) and yeast (Yousefi & Karkoodi, 2007). Effects of different probiotics on egg production and quality found in different research are shown in Table 4.

Table 4: Probiotic effects on egg production and quality

Microorganism	Egg Production	FCR	Quality of Egg			References
			Weight	Shell thickness	Yolk Cholesterol	
L. acidophilus	S (+)	S (-)	NS	NS	-	Gallazzi et al., (2016)
B. licheniformis *B. subtilis*	S (+)	S (-)	NS	-	S (-)38%	Kurtoglu et al., (2004)
Lactobacillus spp; *Bifidobacterium spp.,* *Streptococcus spp.,* *Enterococcus spp.*	S (+)	S (-)	NS	-	-	Yörük et al., (2004)
L. acidophilus, *L. casei; Bi. bifidum,* *A. oryzae,* *S. faceium* *Torulopsis spp.,*	S (+)	NS	NS	S {+)	S (-)14%	Panda et al., (2003)
P. acidilactici	NS	S (-)	S (+)	-	S (-)12%	Mikulski et al., (2020)
R. capsulatus	NS	NS	-	NS	S (-)26%	Salma et al., (2007)
S. cerevisiae	NS	-	-	NS	NS	Asli et al., (2007)

Notes: S(+) = Significantly increased, S(-) = Significantly decreased, NS = Not significant, - = Not studied

Chapter 7: Limitations and constraints

Because of the lack of side effects, feeding probiotics appears to be a reasonable concept. On the other hand, due to the difficulty of selecting optimal strains under optimal conditions and the ability of combining them, selecting probiotics is a challenging process. The efficiency of the delivered formulation is influenced by a variety of interspecies combinations and techniques (Nisbet, 2002).

Important issue to address in this regard is to find the optimal dose and correct strain of the probiotic microorganisms for achieving certain required action. Improvement in their form and delivery methods will also help in achieving maximum potential of probiotics (Alagawany et al., 2018; Khan & Naz, 2013). The exact mechanisms through which specific microorganisms works are not completely understood (Khan & Naz, 2013) which needs further study.

However, we also see variations in the findings of researchers with some claiming no extra benefit of probiotic usage and in some case; it also has some drawbacks in using certain species. Prolonged administration of Lactobacillus spp. may have deteriorating effect on rooster reproductive capability as it may affect the semen quality of rooster (Haines et al., 2015).

According to Behrouz et al., (2012), the research on the usefulness of probiotics and their actual impacts on avian health and production performance is riddled with inconsistencies. It underlines the importance of the dose and kind of microorganisms used in these dietary supplements, as well as the conditions under which they are administered.

Synergism between distinct bacterial strains is a phenomenon that is yet poorly understood. The effectiveness of probiotics is to be determined by the dose/day, probiotic strain, condition, and microorganisms found in the gut. The growing air temperature and the prevalence of heat stress, which is becoming an increasing problem among chicken farmers, may be the environmental factor producing inconsistencies in research results. The experimental outcomes are influenced by a variety of factors like as breeding, feeding, water quality, and stresses. Probiotic exposure has been shown to be influenced by feed structure and density. The number of animals employed in the experiment important since controlling hygienic conditions is more difficult with a high number of animals, which may impair the probiotic bacteria's efficiency (Krysiak et al., 2021).

Chapter 8: Future prospects of Probiotic

Supplementation of probiotics in poultry diet not only improve the animal’s overall health but also reduces the disease prevalence in poultry, thus it helps in reducing the cost of the poultry production. Consumer awareness has also prompted poultry producers to abandon traditional antimicrobial treatments. Since probiotics do not result in the development and spread of microbial resistance, they offer immense potential to become an alternative to antibiotics Kabir et al., 2004). As a result, probiotics have emerged as an effective technique for combating the expansion of harmful bacteria and antibiotic-resistant bacteria (Di Gioia & Biavati, 2018). In practice, the starting point was muscle mass gain due to the pressure to improve bird mass gain. Understanding the incredibly intricate ecosystem in the intestines was essential for a breakthrough in this form of therapy (Wan et al., 2019).

Breeders are currently concentrating their efforts on limiting and preventing the spread of harmful bacteria. The feed additive business may focus on the benefits in the future, such as maintaining normal microflora or more accurate strain and dose selection, although this may be a more complex process as the disease's form changes with animal husbandry conditions. Future probiotic research should look on the interactions between different bacterial strains. Interaction-produced metabolites have the potential to be hazardous. This is what happens with *Clostridium perfringens*, for example, which can kill even closely related strains (Timbermont et al., 2009).

Bacteria can, however, exist in symbiosis, with one strain's metabolites having a beneficial effect on another, resulting in a source of nutrition. This is a cross-feeding phenomenon that will serve as a useful benchmark for restoring balance to birds' digestive systems. Probiotics should not be used as alternative for antibiotics if you want to get the most out of them. The critical relationship between the host, the feed, and the microbes must be considered (Ducatelle et al., 2014).

Chapter 9: Prospect of probiotic use in poultry industry of Bangladesh

In Bangladesh, there is a growing interest in finding alternatives to antibiotics for use in poultry production due to due to rising concern regarding the use of antibiotic growth promoters (AGPs) in poultry feed. The use of probiotics is yet to be a popular choice among the farmers in the poultry industry of Bangladesh. The lack of awareness regarding the use of probiotics in poultry production may be the main reason. Also, there was not much research regarding the use of probiotics in Bangladesh, which is also beginning to change. Many pharmaceutical company and importers are importing probiotics and marketing them for commercial use in the poultry farms. Alam & Ferdaushi, (2018) used commercially available probiotics in Bangladesh (Guardizen-M®, Protexin® Boost,Poultry star sol®) in drinking water of broiler and found significantly increased the body weight and daily weight gain of broiler chicks at 28 days along with improved feed conversion. [Guardizen-M®, Dong Bang Co. Ltd., Korea, contains *Lactobacillus plantarum, Lactobacillus bulgaricus, Lactobacillus casei, Lactobacillus acidophilus, Bifidobacterium bifidum, Streptococcus thermophilus, Streptococcus faecium, Aspergillus oryzae, Torulopsis bovina*; Poultry star sol®, manufacturer Biomin and marketed by Renata Ltd., Animal Health Division contains *Enterococcus Faecium, Pediococcus Acidilactici, Bifidobacterium Animalis, Lactobacillus Salivarius*; Protexin® Boost, manufacturer Protexin Animal Health and distributed by Elanco (Bangladesh) Ltd. contains *Lactobacillus plantarum, Lactobacillus delbrueckii ssp. bulgaricus, Lactobacillus acidophilus, Lactobacillus rhamnosus,Bifidobacterium bifidum, Streptococcus thermophilus, Enterococcus faecium*]

As the concerns among consumers are rising regarding antimicrobial resistance, people are starting to raise questions about the production systems in poultry industry. So, the awareness among the farmers should be raised in grass root level. Farmers should be also informed about the proper management in poultry production. As it is clearly indicates that use of probiotics helps in reducing the disease prevalence in poultry and also improves animal health (Kabir et al., 2004). The farmers in Bangladesh need to be encouraged to use probiotics to help in reducing production cost.

Chapter 10: Conclusions

As the world's population is increasing, the demand for protein from animal source will increase too. People of current generation are also raising their voice about trends in animal production, how the animals are reared and raised. Antibiotic use in meat and egg production needs to be decreased to appease these concerned consumers. For that probiotic can play a great role as an alternative to antibiotic use. As we can see that many strains of probiotic microbes improve the growth rate of poultry, though the results may vary. Also, many probiotics have positive effects on feed intake and feed use efficiency. However, the results are inconsistent in different studies with different probiotic use. Probiotics effect on carcass quality and yield are of little significant. Therefore, to determine the effect of probiotic on carcass quality and yield more accurately, more studies need to be conducted. Some probiotics affect intestinal histomorphology favorably. Immunomodulatory benefits are additional advantages for safe meat and egg production along with economic benefits due to prevention of bird loss or treatment expenditure. Probiotics could be a potential alternative to antibiotic feed additives to manage the enteric pathogen load in poultry, by reducing intestinal colonization and spread of common zoonotic and other enteric pathogens. Probiotics improve animal health and it also improves the immune system of poultry. Although significant amount of work is showing positive impact of using probiotics in feed on poultry production, still more research is needed to come out with some standard protocol for their application.

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