

Beneficial Effects of Probiotics and Prebiotics in Livestock and Poultry: The Current Perspectives

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Abstract

The microbial population in the gastro-intestinal (GI) tract is very complex and consists of different groups of microbes and the GI system is the place where complex interactions occur between feed, microbes and host cells. Probiotics, which are live microorganisms provides a positive impact on the host by altering the intestinal microbial balance, thus helping to reduce the harmful effects of pathogenic bacteria in the gut. In livestock as well as poultry, probiotics have been shown to improve growth performance, feed conversion efficiency and immune responses. They exert their action by competitive exclusion or producing antibacterial substances that are detrimental to pathogenic microbes. Similarly, prebiotics, which are non-digestible feed supplements, are selectively fermented by beneficial microflora and are utilized by them to exclude the pathogenic microbes. These non-digestible substrates comprises of oligosaccharides which also has the ability to stimulate absorption of several minerals in intestine. Also, nowadays, combination of Probiotics and Prebiotics (Synbiotics) are effectively used to counter the negative impact of stress factors or pathogens in animal and poultry production systems. Presently, the prospects of identifying or evolving novel strains of probiotics using various modern amenities and techniques have been explored. For this purpose, polymerase chain reaction (PCR) technique, 16S rRNA sequencing, real time PCR and microarray techniques are utilized. These techniques are capable to assess the influence and interaction of intestinal microflora on host systems. The technique of genetic engineering has also been

used to modify the effects of existing strains or to create novel probiotics that can play multiple roles in the intestinal environment.

Key words: cattle, immunity, livestock, production, probiotics, prebiotics, poultry, swine

Introduction

Probiotics or direct feed microbials (DFM) are naturally occurring and selected live microorganisms that create a positive impact on the physiological status of the host. This is often accomplished by their ability to alter the intestinal microbial balance in a beneficial manner, which in turn will improve the health and well being of animals, birds or human beings (Anandakumar and Lakshminarayan, 1997; Bengmark, 1998; Fuller, 2001). Probiotics can be single or mixed-culture of microorganisms that improve the gut microbial environment by displacing harmful bacteria that are often detrimental to the sustenance of living beings. Probiotics may also include fungi and yeast, besides bacteria. Generally, live apathogenic bacterial strains belonging to genus *Lactobacillus*, *Streptococcus* or *Enterococcus*, are used in livestock and poultry. The desirable qualities for a good probiotic are; non-pathogenic, non-toxic, symbiont, and more importantly capable to resist the adverse environment of gastrointestinal tract. Also, they must be able to adhere to the intestinal epithelium and be compatible with other feed additives. As growth promoters, probiotics have been found to increase feed conversion efficiency, improve growth performance, and improve immune responses in livestock and poultry (Balevi *et al.*, 2001; Brashears *et al.*, 2003). They are capable

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of stimulating the immune system of animals and birds to fight against infectious agents and other stress factors (Fuller, 2001; Dalloul *et al.*, 2005; Lee *et al.*, 2007). Nowadays, probiotics have successfully replaced the antibiotic growth promoters which were once prolifically used to counter the effects of stressors and harmful microbes. Antibiotics in animal feed was often a contentious issue as their presence as residues in animal and poultry products was undesirable and their illegitimate use paved way to the evolution of drug resistant microbes. Similar to probiotics, prebiotics (food for microflora), which are fermented feed ingredients, are capable of changing the composition and activity of gut microflora by selectively providing suitable substrates for the beneficial bacteria. Currently, dietary non-digestible oligosaccharides are considered as prebiotics which stimulates the growth of non-pathogenic bacteria (Bengmark, 2002). They are generally short-chain carbohydrates that alter the composition or metabolism of the gut microbiota by giving rise to short-chain fatty acids (SCFA), on fermentation. They improve health in a way similar to probiotics, all the while being cheaper, carrying less risk and easier to incorporate in the diet when compared to probiotics (Macfarlane *et al.*, 2006). Also, probiotics and prebiotics can be used together as 'synbiotics' to improve the production potential of herds and flocks. Together, these growth promoting feed additives, combined with scientific principles of health care, management and biosecurity, are expected to play a major role in bolstering animal and poultry production in India, in the years to come.

Probiotics- The Mode of Action

Probiotics maintain a proper balance of useful bacterial population in the intestine of animals and birds, which is important for their efficient feed conversion, growth and productivity (Fuller, 1989; Seema and Johri, 1992; Ivanov, 2003). These live gram-positive microbial additives inhibit the harmful bacteria that produce toxins or invade the host. The principal mechanisms by which they exert their beneficial effects are enlisted.

Competitive exclusion/Barrier effect: The idea of competitive inhibition or exclusion of pathogens

was derived when it was first observed that oral administration of fowl intestinal microbes in young chicks reduced the incidence of *Salmonella* infection (Mulder, 1991). Later it was found to be due to the competitive exclusion of the harmful bacteria by other non-pathogenic intestinal dwellers such as Lactobacilli, which competes with the pathogens for adherence on the intestinal surfaces. Thus the incapability of the pathogens to attach favored its removal from the gastrointestinal tract along with the digesta. This key feature of probiotics is nowadays widely used in animal and poultry production systems to inhibit the harmful effects of pathogenic bacteria like *Salmonella*, *Escherichia coli*, *Clostridium perferinges* and *Campylobacter jejuni* (Jin *et al.*, 1997).

Antibacterial substances / Bacterial antagonism:

Probiotic organisms such as *Lactobacillus* are able to inhibit the growth of pathogens like *Salmonella* sp., *Staphylococcus* sp., and *E. coli*, by producing several bactericidal substances. The antibacterial substances can be bacteriocins, lactocin, lactocidin, acidolin, acidophilin, reuterin, bulgaricin, organic acids (lactic and acetic acid), lysozyme, lactoferrin, hydrogen peroxide or lactoperoxidase (Jin *et al.*, 1997). Bacteriocins have a bactericidal action; acidolin inhibits Gram-positive organisms and reuterin inhibits bacteria, yeast and fungi. Organic acids and volatile fatty acids (lactic, acetic, butyric and propionic acids), produced by probiotic organisms decrease the intestinal pH and inhibit the growth of pathogenic bacteria. The antibacterial action produced by *L. acidophilus* is primarily due to a combination of factors viz. acids, hydrogen peroxide, and bacteriocins. Anti-enterotoxin substances produced by probiotics like *L. bulgaricus* are also capable of neutralizing enterotoxins produced by pathogens.

Exclusion of nutrients: The probiotic strains grow well in the gut environment and colonize to efficiently utilize the available substrates. Lactic acid producing bacteria, utilizes the nutrients that would otherwise be available to the pathogens. Thus they compete with harmful microbes for use of available nutrients in the intestinal tract (Nava *et al.*, 2005).

Improving nutritional status: Probiotic microbes stimulate appetite, improve palatability of the feed, and increase the digestion of nutrients in host. They stimulate the growth of cellulolytic bacteria and facilitate the digestion of fiber. *Lactobacillus* spp. isolated from birds have been found to secrete digestive enzymes like amylase, protease and lipase, which enhance the digestion and absorption of carbohydrates, proteins and fats, respectively, and thereby improving the feed conversion efficiency (Nava *et al.*, 2005). They also help in metabolism of minerals and synthesis of vitamins. *Lactobacillus* along with yeast culture is responsible for synthesis of B-vitamins which are responsible for growth and metabolism in birds.

Reducing ammonia production: Excess of ammonia in litter damages the epithelial lining of digestive tract and cause keratoconjunctivitis and associated problems in poultry units. In this regard, the probiotics acts as antagonists of ammonifying bacteria that predominate in the intestine of birds. They reduce the microbial breakdown of nutrients, which results in lower ammonia content in the lumen. The supplementation of probiotics in feed such as *Lactobacillus casei* helps in decreasing the urease activity in the small intestine of chickens and thus a subsequent decrease of non-protein nitrogen, uric acid, ammonia and urea (Anandakumar and Laksmimarayan, 1997; Fuller, 2001). Probiotics like *Streptococcus faecium* and *Bacillus subtilis* also reduces the concentration of ammonia in the excreta of birds.

Immunostimulation: Probiotics plays a crucial role in the development of immune competence in neonates (Balevi *et al.*, 2001). *Lactobacillus* or other host specific strains administered orally for first week of life has been shown to reduce mortality by stimulating the immune system. They exert immunostimulatory action by increasing the production of immunoglobulins; stimulation of cell mediated immunity; elevated production of interferons; increasing the macrophage, lymphocyte and natural killer (NK) cell activity; regulating oxidative burst and degranulation of heterophils (Koenen *et al.*, 2004). *Lactobacillus* have been reported to increase the intra-epithelial lymphocytes of intestinal lymphoid tissue, which

responds to microbes by secreting immunoglobulin A (IgA), and thereby providing local immunity (Balevi *et al.*, 2001; Haghghi *et al.*, 2006).

Probiotics in livestock and poultry production systems

The disturbances in the balance of gut microflora will obviously result in proliferation of pathogens. This scenario will in turn reduce the production performances of the animals or birds thereby causing financial loss to livestock and poultry producers (Pal and Chander, 1999; Sauter and Blum, 2003). For prevention of such a situation, usually antibiotic growth promoters were used as feed additives. In long run, this has created public health concerns in the form of presence of antibiotic residues in milk and meat products as well as paving way for evolution of antibiotic resistant pathogens. In this context, the concept of probiotics has evolved which could be used in feed in order to maintain a balanced microflora to enhance the health and productivity. Probiotics have numerous advantages as they improves digestibility and utilization of nutrients, increases growth rate and productivity, inhibits diseases producing organisms, prevents diarrhoea due to bacterial infections, reduces stress after vaccination, antibiotic therapy and transportation, and stimulates the immune responses. Regular and judicious use of probiotics has a striking effect on the immune system that includes enhanced production of natural interferons, immunoglobulins and stimulation of cell-mediated immunity (Koenen *et al.*, 2004). In poultry, probiotics improves fertility and hatchability of eggs, increases egg production and quality and lower the mortality of chicks, apart from the above mentioned merits. The probiotics commonly used may comprise of single or multiple strain(s) of bacteria or yeast. Commonly used strains are *Streptococcus faecium*, and *Lactobacillus sporogenes*. *Lactobacillus acidophilus*, *Lactobacillus bulgaricus*, *Lactobacillus casei*, *Lactobacillus plantarum*, *Lactobacillus cellobiosus*, *Lactobacillus salivarius*, *Streptococcus thermophilus*, *Enterococcus faecium* and *Saccharomyces cerevisiae* (yeast) are also used (Ehrmann *et al.*, 2002). Given the host specific strain of bacteria and optimal concentration of viable cells, the beneficial impact

Dhama and others

of probiotics supplementation can be significant. In animal production systems, probiotics are frequently used for improving the health status as well as production performances especially in cattle, swine and poultry.

Cattle: Probiotics have been well known for their ability to control infectious diseases, improve productive performances and increase dry matter digestibility in cattle (Cole *et al.*, 1992; Gupta and Gupta, 2007; Yasuda *et al.*, 2007). Quite often, lactic acid bacteria based-probiotics have prevented intestinal infections by pathogenic bacteria, and also found to decrease stress and stimulate host immune response (Nocek *et al.*, 2002). It has been suggested that cattle transported for long distances appear to show a relatively greater response to probiotic, in comparison to non-stressed ones (Wagner *et al.*, 1991). When compared to adult cattle, in calves, diarrhea is the most common problem, which continues to cause considerable economic loss to the livestock producers. Also, acute enteric infections are the single most important cause of morbidity and mortality in calves (Dutil *et al.*, 1999). Antibiotics are commonly used for the treatment in such cases, but growing concern due to antibiotic residues in food products and the emergence of antibiotic-resistant pathogens has promoted interest in probiotics. Cole *et al.* (1992) has reported that yeast culture caused a favorable response by morbid calves. During therapeutic treatment in calves, it has been found suitable to provide probiotics simultaneously as it reduced the percentage of calves that required therapy and the amount of the drug needed (Timmerman *et al.*, 2005). Like wise, a balance between microorganisms that produces or utilize lactic acid is critical in maintaining a stable ruminal environment in adult cattle (Owens *et al.*, 1998). It is suggested that feeding of probiotics, *Lactobacillus sp.* and *Enterococcus faecium* provides a constant level of lactic acid to the rumen microbiota (Nocek *et al.*, 2002). Also, it has been documented that the use of specific strains of yeast as probiotics may stimulate lactic acid utilization in rumen. Such benefits have a positive influence on postpartum performance in dairy cattle and also help in preventing the incidences of metritis (Nocek *et al.*, 2002; Otero *et al.*, 2006). Similarly, a

synbiotic (probiotics together with prebiotics) consisting of *Lactobacillus casei* and dextran has the ability to increase the milk production in cattle (Yasuda *et al.*, 2007). Probiotic microbes like *E. coli* or *Lactobacillus acidophilus* which produces colicins has been reported to reduce the *E. coli* O157:H7 strain in cattle, which is also a food-borne pathogen in man as a result of consumption of contaminated meat and water (Schamberger *et al.*, 2004).

Swine: In swine, probiotics have been assigned to play a significant role in providing supportive care to piglets during their initial part of life. Early weaning of piglets is often accompanied by reduction in growth and diarrhoea. After the withdrawal of sow's milk, the piglets are highly susceptible to enteric diseases due to the altered balance between beneficial microbiota and intestinal bacterial pathogens. Probiotics and prebiotics are advantageous nutritional options in this regard (Lalles *et al.*, 2007). It is suggested that the daily oral supplementation of probiotic *Enterococcus faecium* strain from birth to weaning reduces the rate of piglets suffering from diarrhea (Zeyner and Boldt, 2006). Like wise, overall dietary supplementation of yeast has a positive effect on body weight gain and feed intake of piglets (Li *et al.*, 2006). The administration of *L. acidophilus*, caused an increase in the number of lymphocytes and lymphoid cells in lamina propria and intra-epithelial lymphocytes (IEL) in the small intestine (Babinska *et al.*, 2005). The probiotic bacteria is also capable in increasing the production of short chain fatty acids (SCFA) as a result of accelerated breakdown of carbohydrates that are normally resistant to indigenous bacteria (Sakata *et al.*, 2003). A probiotic *E. coli* strain (Nissle), was found to prevent acute secretory diarrhea and the efficacy of its administration for preventing the diarrheal effects of entero-toxigenic *E. coli* has been studied (Schroeder *et al.*, 2006). For reducing the chlamydial infection, probiotic *E. faecium* was used by Pollmann *et al.* (2005), which considerably lowered the frequency of chlamydia-positive cases and reduced the rate of carryover infections in piglets. *E. faecium*, when supplemented in a concentration of 5×10^8 CFU/kg feed to the gestation and lactation diets of gilts,

was found to significantly improve feed intake, litter size and weight gain (Bohmer *et al.*, 2006). The probiotic *E. faecium* seems to influence the transport and barrier functions of pig small intestine and increased the absorption of glucose (Lodemann *et al.*, 2006). Similarly, *Lactobacillus acidophilus*, in swine, is both acid and bile tolerant and was found to inhibit the growth of *E. coli*, *Salmonella typhimurium*, *Staphylococcus aureus* and *Bacillus cereus* (Tsai *et al.*, 2005).

Poultry: The intestinal microbiota, epithelium, and immune system provide passive and active resistance to enteric pathogens in birds. Inhibition of pathogens by the intestinal microbiota has been called bacterial antagonism or competitive exclusion. Lactobacilli, isolated from chicken gastrointestinal tract, was examined and found useful for their potential probiotic properties and inhibitory activity against enteropathogenic bacteria like *Salmonella*, *E. coli* and *Clostridium perfringens* (Kizerwetter-Swida and Binek, 2005). Currently, the increased bacterial resistance to antibiotics has forced poultry enterprises to eliminate sub-therapeutic use of antibiotics as growth promoting agents (Dhama *et al.*, 2007a, b). An alternative approach to sub-therapeutic antibiotics in poultry is the use of probiotic microorganisms or synbiotic combinations of prebiotics and probiotics (Patterson and Burkholder, 2003). The use of defined probiotic cultures in the poultry industry has recently become more common (Gupta and Chauhan, 1999; Singh and Chauhan, 2002; Torres-Rodriguez *et al.*, 2007; Dhama *et al.*, 2007a,b). Probiotic organisms like *Pediococcus*, *Lactobacillus* and *Saccharomyces* strains have significantly contributed to lowering incidences of coccidiosis, which is the major protozoan disease of poultry (Dalloul *et al.*, 2005; Lee *et al.*, 2007). It was recently demonstrated that *Pediococcus acidilactici*-based probiotic has effectively enhanced the resistance of birds and partially protected against the negative growth effects associated with coccidiosis (Lee *et al.*, 2007). The cytokine and oocyst production was assessed after using a commercial Lactobacillus-based probiotic, which clearly underlined the positive impact of the probiotic on cellular immune

responses of infected broilers to *Eimeria sp.* (Dalloul *et al.*, 2005). A synbiotic consisting of *Lactobacillus casei* and dextran elicited an enhanced humoral immune response and this may be useful in developing an oral immunoadjuvant in birds to protect against infectious diseases (Ogawa *et al.*, 2006). Many studies have been undertaken to test the effect of probiotics on the production efficiency of broiler chickens (O'Dea *et al.*, 2006). Huang *et al.* (2004) has also reported that some inactivated probiotics, similar to live ones to have the beneficial effects on production performance and immune response in broiler chickens. For application in broiler production, a multispecies and chicken-specific probiotic preparation in fluid form, consisting of 7 *Lactobacillus* species isolated from the digestive tract of chickens was recently developed (Timmerman *et al.*, 2006). The *Lactobacillus* strains that were evaluated showed modulating effects on the immune system of layer and broiler chickens. Immunoprobiotic lactobacilli can have a positive effect on humoral and cellular immune responses, but the *Lactobacillus* strain to be used and effective dose of lactobacilli to be administered need to be optimized (Koenen *et al.*, 2004). It has been also reported that thickness of the medial and lateral wall of the tibia, percentage ash, and P content were significantly improved by probiotics, thus portraying its effects in the skeletal system of birds (Mutus *et al.*, 2006).

Prebiotics

Utilizing oligosaccharides, that can selectively stimulate one or a limited number of commensal bacteria, is another method used to manipulate the gut ecosystem (de Vaux *et al.*, 2002). These substrates popularly known as 'prebiotics' would selectively enrich beneficial organisms capable of metabolizing them and displace pathogens from the gut microflora. Presently, the prebiotic is defined as "a substrate or ingredient that is non-digestible for the host but is fermented selectively by some of the beneficial microflora in gut". They are capable of altering the microbial balance in a beneficial manner to the host (Zopf and Roth, 1996). *Salmonella*, *E. coli* and many other gram-negative microorganisms are unable to utilize fructo-oligosaccharides and therefore, their growth is inhibited. The commercially available

Dhama and others

prebiotics often comprises of oligosaccharides of fructose or mannose viz. mannan oligosaccharides (MOS) or fructo-oligosaccharides (FOS). It has been reported that mannan-oligosaccharides from yeast cell wall works by providing specific binding sites to enteric pathogens, thereby reduces their adherence to the intestinal tract. Later these non-digestible oligosaccharides pass through the gut with the pathogens attached, thus assisting in their effective clean up. Fructo-oligosaccharides and other prebiotics are not digested by intestinal enzymes and favor the growth of Lactobacilli, which can utilize the compound as an energy source (Roberfroid, 2001; Roberfroid, 2007).

The concept of prebiotics, which is a recent entry to the class of growth promoters, concerns with the modification of intestinal flora by their inherent ability to get selectively fermented (Roberfroid, 2001; Van Loo, 2004). Prebiotics, having a synergistic effect with probiotics, have systemic effect on utilization of feed ingredient, stimulation of immunity and neutralization of toxins and they exert their action by lowering pH through lactic acid production and thus inhibiting colonization of pathogenic bacteria (Simmering and Blaut, 2001; Patterson and Burkholder, 2003). The effects seem to be specific for the type of carbohydrate and related to the rate of fermentation by the intestinal flora and appear to depend on the dose ingested (Scholz-Ahrens *et al.*, 2001). To deprive *E. coli* O157:H7 of nutrients or to feed diets containing nutrients for which the pathogen does not compete well, was found to

be the most attractive way of restricting the growth of this organism in cattle (Duncan *et al.*, 1999). The inability of *E. coli* to reach high numbers in the rumen, due to the toxicity of volatile fatty acids generated due to the prebiotic substrates has been studied (Wallace *et al.*, 1989; Duncan *et al.*, 1999). Research over the last decade has also shown that lactic acid bacteria can increase resistance to disease and can be enriched in the intestinal tract by feeding specific carbohydrates. Also, these non-digestible oligosaccharides have been found to stimulate absorption of several minerals and to improve bone mineralization. It is reported that the prebiotics increases the availability of calcium, magnesium, zinc, and iron to the host (Scholz-Ahrens *et al.*, 2001).

Many workers have done studies to assess the capabilities of prebiotics in animals and birds. The effects of mannanoligosaccharide (MOS) supplementation on haematological and immunological parameters, in birds, clearly showed that MOS is capable in elevating IgG and IgM levels, thus improving the host's ability to resist disease (Cetin *et al.*, 2005). Similarly, isomalto-oligosaccharides (IMO) derived from *Leuconostoc* was found to selectively stimulate the growth of *Bifidobacterium* and *Lactobacillus* in presence of pathogenic *Salmonella* or *E. coli*, indicating the value of these oligomers for intestinal microflora modification in birds (Chung and Day, 2004). Recently, in swine, polysaccharides derived from Cassia seeds have shown to provide a dynamic change in the intestinal microflora profile (Deng *et al.*, 2007).

Table 1. Salient features of probiotics and prebiotics

Probiotics	Prebiotics
Primarily of host origin and non-pathogenic	Must be non-digestible
Exclusion of pathogenic microbes	Short-chain carbohydrates, nourishes the desirable microflora
Adherence to intestinal epithelium,	No absorption in intestine
Resistant to acid and bile Withstand feed processing temperatures	Not get hydrolyzed in the gut
Rejuvenates the desirable microflora	Medium for accelerating growth of beneficial microflora
Persistent presence in GI tract	Capable to undergo fermentation
Production of antimicrobial compounds	Synergistic effect with probiotics
Stimulates the host system	Inexpensive and easier immune incorporation

Dhama and others

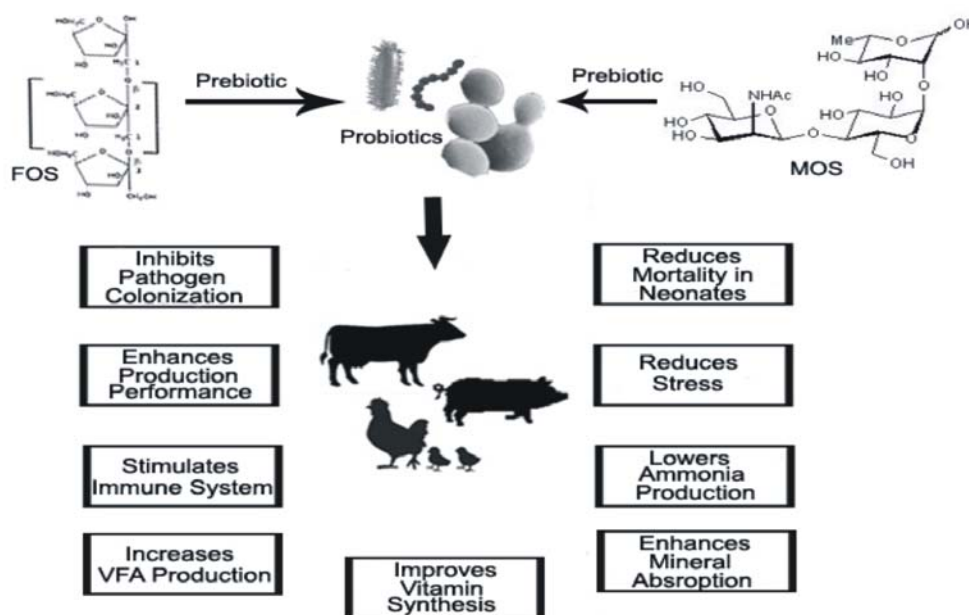


Fig. 1. Beneficial effects of prebiotics and probiotics in livestock and poultry

Current Trends

The scientific advances and ever improving amenities in the field of functional food research have paved way for the evolution of novel strains of probiotics, exploiting the various modern tools and molecular biology techniques. Presently, for the differentiation and strain identification of probiotics in feeding stuffs, polymerase chain reaction (PCR) is considered by many international organizations (Leuschner *et al.*, 2004). RAPD-PCR typing is another feasible method to identify and differentiate probiotics from other faecal microbes (De Angelis *et al.*, 2007). Also, utilizing 16S rRNA gene sequencing, microbiota from different regions of the gastrointestinal (GI) tract of birds has been analyzed on which, *Lactobacillus aviarius* and *Lactobacillus salivarius* were found to be the predominant species among lactobacilli (Gong *et al.*, 2007). Similarly, in cattle, a strain-specific 16S/23S rRNA intergenic spacer regions (ISR) based assay was developed for the detection of viable *Lactobacillus* on feed which helped in

demarcating them from endogenous bacteria (Flint and Angert, 2005). A real time PCR assay has been recently used to distinguish *Enterococcus* spp., *E. faecium* and *E. faecalis*, from the probiotic strain (Vahjen *et al.*, 2007). Also, terminal restriction fragment length polymorphism (T-RFLP) analysis of 16S rRNA is helpful in finding out the impact of probiotics on intestinal microbiota (Lan *et al.*, 2004). *In vivo* detection of probiotic organisms using fluorescence microscopy of gut samples has been facilitated by introducing the plasmid containing the green fluorescent protein (GFP) (Schultz *et al.*, 2005). Like qualitative detection, quantitative information on microflora and their contribution to the gastrointestinal tract of animals is essential to formulate feeds, for which a colony hybridization technique using probes with specific nucleotide sequences (Macha *et al.*, 2004) or fluorescent *in situ* hybridisation (FISH) have been used (Mountzouris *et al.*, 2006). Now, real-time polymerase chain reaction (PCR) and microarrays have become more promising methods to comprehensively

analyze the gut microflora and to study their influence on intestinal ecosystems (Carey *et al.*, 2007).

Like wise, exploiting genetic engineering approaches, it is possible to strengthen or create completely novel probiotics. If designed carefully, the development of genetically modified probiotics has the potential to revolutionize alimentary health (Steidler, 2003). Lactic acid bacteria have been modified by genetic engineering (recombinant DNA technique) methods to produce new varieties (Ahmed, 2003) or to get them modified for use in oral immuno-therapeutic applications, such as vaccination and delivery of immunoregulatory substances (Karimi and Pena, 2003). Utilizing recombinant DNA technology, Paton *et al.* (2005) has incorporated the receptors for bacterial toxins on the surface of probiotic organisms, which avoided their binding to the intestinal receptors. They also evolved a non-pathogenic *E. coli* strain capable of producing a chimeric lipopolysaccharide that can bind heat-labile bacterial enterotoxins. Such toxin-binding probiotics have considerable potential for its use against enterotoxemia in animals. Various methods are also recently devised for improving the effects of probiotics. For the protected oral delivery of probiotics, DNA extracted from salmon milt was used to prepare gel-complexes by cross-linking with gelatin and carrageenan which exhibited higher protective capability and enabled the probiotic organism to tolerate the inclement environment in the intestinal tract (Jonganurakkun *et al.*, 2006). *Salmonella*-specific bacteriophages when administered orally along with probiotics to the chickens had an additive effect and improved protection against *Salmonella* infection in chicks (Toro *et al.*, 2005).

Conclusion

In a highly competitive world with ever increasing productive demands, animals and birds are stressed by various factors. The intensive system of livestock or poultry rearing promotes growing young ones, in the absence of dam, thus depriving them from acquiring enough protective immunity, which enables easier invasion of various infectious pathogens. In this context, combined with good hygiene and management, supplementing probiotics and prebiotics holds

much promise as they functions effectively to maintain growth and production in animal husbandry operations and protect the herds against infectious agents. Moreover, these feed additives have no side effects, when compared to its antibiotic counterparts. Manipulation of the intestinal microbiota by administration of probiotics or prebiotics has also shown to enhance humoral and cellular immune responses, which could stimulate the development of natural antibodies. With multiple utilities and myriad potential benefits like modification of host gastrointestinal functions, immuno-stimulation, exclusion and inhibition of pathogens in the intestinal tract and enhanced nutrient absorption, these 'beneficial bacteria' could easily solve the problems that are encountered frequently in animal production units. Also, nowadays, combination of probiotics and prebiotics (synbiotics) are effectively used to overcome the negative impacts of stressors or pathogens in animal and poultry production systems. Aside to this, the scientific and technological advancements allow genetic manipulations of probiotic microbes to improve upon its potential and facilitate the evolution of new generation beneficial microbes. Presently, as a result of scientific advancement; the polymerase chain reaction (PCR) technique, 16S rRNA sequencing, real time PCR and microarray techniques are utilized to identify and understand the underlying mechanisms of host-microflora interactions. These techniques are capable of assessing the influence of intestinal microorganisms on host metabolism and their nutrient status. Recombinant DNA technique is also recently used to strengthen the effects of existing strains or to create novel multi-utility probiotics. Thus, probiotics or prebiotics as growth promoters have brought a new era in animal production and health care management which could be seen as an effective and economical way to improvise the livestock and poultry production systems, to make them evolve as lucrative enterprises in the near future.

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Dhama and others

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Dhama and others

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Dhama and others

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