Probiotics for Human Health: Current Progress and Applications

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Ruby Yadav and Pratyoosh Shukla

Abstract

Probiotics are live microbial cultures which enhance the beneficial gut microflora to improve the overall health of the host. It is a rising field in dairy food industry with significant growth potential. Probiotic food supplements have attracted a lot of attention and revealed a remarkable growth in this field. Various bacteria, yeast, and molds can be used as probiotics, but most commonly used microorganisms are lactic acid bacteria (LAB). LAB is involved in the fermentation of dairy products, foods, and beverages and produces lactic acid as the end product of fermentation. Among LAB, most commonly used bacteria which exhibit excellent probiotic properties belong to *Lactobacillus* and *Bifidobacterium* genus. These bacteria produce a variety of compounds such as organic acids (lactic acid and acetic acid), antimicrobial compounds (bacteriocins), nutraceuticals, vitamins, enzymes, etc. Probiotics are also consumed in combination with prebiotics known as synbiotics. Prebiotics are nondigestible carbohydrates, which pass through the small intestine in unmetabolized form and undergo fermentation in the large intestine. The fermentation products act as an energy source for indigenous gut microflora. The food products containing probiotics and prebiotics result in the enhancement of the microflora which promotes the overall gut health. This chapter enclosed a brief knowledge of different probiotic strains, probiotic foods, and their health applications.

Keywords

Probiotics • Lactic acid bacteria • Prebiotics • Health application

R. Yadav • P. Shukla (✉)
Enzyme Technology and Protein Bioinformatics Laboratory, Department of Microbiology, Maharshi Dayanand University, Rohtak 124001, Haryana, India
e-mail: rubyyadav67@gmail.com; pratyoosh.shukla@gmail.com

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6.1 Introduction

Probiotics are microorganisms that are involved in providing health benefits to the consumer, when administrated in adequate amounts (Hill et al. 2014). As probiotics exhibit various health benefits, these are used for the production of food products like yogurt, fermented milk, etc. Lilly and Stillwell described the term probiotics and defined as the substances which are secreted by one microbe and in turn affect the other microbes. Fermented milk was the first recorded probiotic food. Elie Metchnikoff published his book *The Prolongation of Life* which boosted the research in probiotic area. After experimenting in the Bulgarian peasants, he concluded that longevity in them was due to consumption of large amounts of sour milk. This milk contains LAB which removes the pathological reactions like autotoxication by the gut's normal flora (Metchnikoff 1907). After this, the researchers started working on LAB importance in human health and diseases. Probiotics include bacteria, non-pathogenic yeast, and molds (Ouwehand et al. 2002). LAB produce lactic acid as their end product of fermentation and are ordinarily used for the production of yogurt, fermented milk, or other fermented foods. These are gram-positive, oxidase- and catalase-negative, sporulating rods and cocci. The genera comprise of *Lactobacillus*, *Leuconostoc*, *Lactococcus*, *Streptococcus*, *Pediococcus*, *Enterococcus*, *Carnobacterium*, *Sporolactobacillus*, *Bifidobacterium*, *Oenococcus*, *Sporolactobacillus*, *Vagococcus*, *Tetragenococcus*, *Weissella*, etc. These are widely spread in nature and also found in many food products as well as in oral, genital, and intestinal cavity of animals and human. *Lactobacillus* is the most important genus of LAB which include more than 80 species, and these are present in milk and dairy products like cheese and yogurt. Most microorganisms which are used as probiotics belong to genera *Lactobacillus*, *Enterococcus*, and *Bifidobacterium* (Holzapfel and Wood 2014). Some of strains which are showing good probiotic properties are *Lactobacillus acidophilus*, *L. lactis*, *L. casei*, *L. plantarum*, *L. helveticus*, *L. salivarius*, *L. johnsonii*, *L. bulgaricus*, *L. reuteri*, *L. rhamnosus*, *L. delbrueckii*, *L. fermentum*, *Bifidobacterium bifidum*, *B. longum*, *B. breve*, *Streptococcus thermophilus*, *Enterococcus faecium*, and *Saccharomyces boulardii.*

Various beneficial effects produced by LAB consumption involve improvement of the health of the intestinal tract, increasing the capability of the immune system, synthesis and increase of availability of the nutrients, reduction of the symptoms of lactose intolerance, decreasing the frequency of the allergy in the individuals who are susceptible to allergy, and reducing the risk of cancers in the consumer (Goyal et al. 2013, Savadago et al. 2006). The mechanisms of the action of probiotic by which they employ their effects are largely unidentified but may involve in the modification of the pH of the gut. They decrease the concentration of the pathogens by producing antimicrobial compounds and by competing for the binding sites and receptor sites for the growth factors and for the nutrients available to the pathogen. The food products which contain probiotics and prebiotics affect the functionality of the foods, which results in the enhancement of the microflora that promotes the gut health. The probiotic bacterial species increases the growth of the beneficial microorganisms, removes of the harmful bacteria, and supports the innate immunity

of the body. A probiotic strain should fulfill the following selection criteria: safety, viability during storage, acid tolerant, bile tolerant, other epithelial cells of the gut, and able to colonize the intestinal tract, stimulate immune responses, and modulate normal microflora (Saad et al. 2013; Lee et al. 2014). The viability and functionality cannot be lost during their technological integration into food products, and it must not involve the creation of unpleasant textures or flavors. The technological, operational, and safety characteristics are accepted for the selection of the probiotics.

Processes like food digestion and nutrient integration occur in the small intestine, whereas the indigestible carbohydrates known as prebiotics can cross the small intestine, and, thus, they pass into the large intestine for the stimulation of the growth of probiotic bacteria. Prebiotics can be defined as nondigestible food products which stimulate growth and activity of bacteria in the host's intestine. So, these are dietary substances which support the growth of wanted bacteria over the unwanted one present in the gut. Prebiotics mainly include breast milk oligosaccharides, short-chain carbohydrates, inulin, galacto-oligosaccharides, oligofructose, and lactulose. Food containing prebiotics are garlic, wheat, bananas, honey, leeks, onion, etc. Synbiotics are the combination of probiotics and prebiotics. These contain probiotics which are beneficial bacteria and prebiotics which are indigestible products for the enhancement of growth of good bacteria. Fermented dairy products, kefir, and yogurt are the examples of the synbiotic food products. The most common synbiotics include fructooligosaccharides (FOS) and bifidobacteria, inulins and *Lactobacillus* GG, and bifidobacteria and lactobacilli with fructooligosaccharides. Nowadays metabolic engineering techniques for designing new probiotics in food industry have gained a lot of attention (Singh and Shukla 2014). Genetic modification of microbes involves the introduction of desired genes that may have a positive impact on the food industry (Gupta and Shukla 2015).

6.2 Probiotic Foods

Most commonly used probiotic product is yogurt. In spite of this, cheese, milk either fermented or unfermented, smoothies, juice, nutrition bars, cereals, and infant formula feed all are examples of probiotic food (Ranadheera et al. 2010). Along with food, probiotics can also be available in the form of liquid, powder, gel, granules, paste, capsules, sachets, drugs, and as dietary supplements. All these forms contain a large number of bacteria which remain in a stable condition. These forms of products are more convenient as we can deliver a large number of bacteria from manufacturer to customer in stable condition. There are various products made by different companies using different strains of probiotics. These products have various clinical or therapeutic applications. The use of probiotics in food or other products depends on many factors like stability of product, humidity, pH, age of customer, quantity or number of bacteria used, etc. These products are helpful for all age groups like children, infants, and old age. The aim of using these microbes as probiotics is mainly to increase the beneficial flora of the host.

In the United States, dairy products (e.g., fermented milk and yogurt) are the food products that contain the probiotic exclusions. LAB are associated with the fermented milk (Shah 2015). The most commonly used bacteria in dairy products (containing probiotics) include *Lactobacillus* and *Bifidobacterium* (Backhed 2012). Probiotics commonly are not the colonizers of the GI tract for long term, but they can stick provisionally to the epithelial layer. They remain metabolically active, although they divide very slowly in the intestine. Milk and milk products contain probiotic bacteria, which improve the beneficial microbiota in the intestine (Isolauri et al. 2001). Probiotics are a group of microorganisms that are involved directly in increasing the resistance of bacteria against intestinal pathogens and thus are involved in the prevention of the diseases. Probiotic bacteria involved in the production of a variety of compounds, which shows an inhibitory effect to the growth of pathogenic microorganisms, include bacteriocins, reuterin, and organic acids such as acetic acids and lactic acids. For the delivery of probiotic microorganisms in the body, food is the common medium. Probiotic microorganisms that are given by food systems have to fulfill some conditions like they have to first survive during the transfer through the upper gastrointestinal tract and then survive in the gut to produce beneficial effects to the host. Fermented foods can have probiotics, prebiotics, or both, and they are associated with good health. Yogurt is a well-known probiotic used today. It contains a very good nutritional value and provides health benefits to the host. The various factors that affect the growth of probiotic bacteria are pH, the presence of hydrogen peroxide and dissolved oxygen, buffering capacity, and concentration of metabolites (lactic acid, acetic acid, etc.).

6.3 Probiotic Microorganisms

Various bacteria, yeast, and molds can be used as probiotics, but most commonly used microorganisms are bacteria, and among bacteria, LAB are more popular. An overview of applications of LAB is given in Fig. 6.1.

Probiotics may be formed by a group of different strains or single bacterium. Probiotic preparations consist of specific strains of *Lactobacillus*, *Streptococcus*, and *Bifidobacterium* either alone or in combination. These three genera are considered to be safe and might be capable of preventing the overgrowth of pathogenic organisms as these are important components of the gastrointestinal flora. The commonly used probiotic bacteria are summarized in Table 6.1.

6.4 Probiotics: Mechanism of Action

Probiotics exhibit numerous and various effects to the host. The probiotic bacteria decrease the luminal pH resulting in inhibition of the establishment of pathogenic bacteria, inhibit the bacterial attack and the attachment of pathogenic bacteria to epithelial cells, and produce the antimicrobial compounds, e.g., defensins and

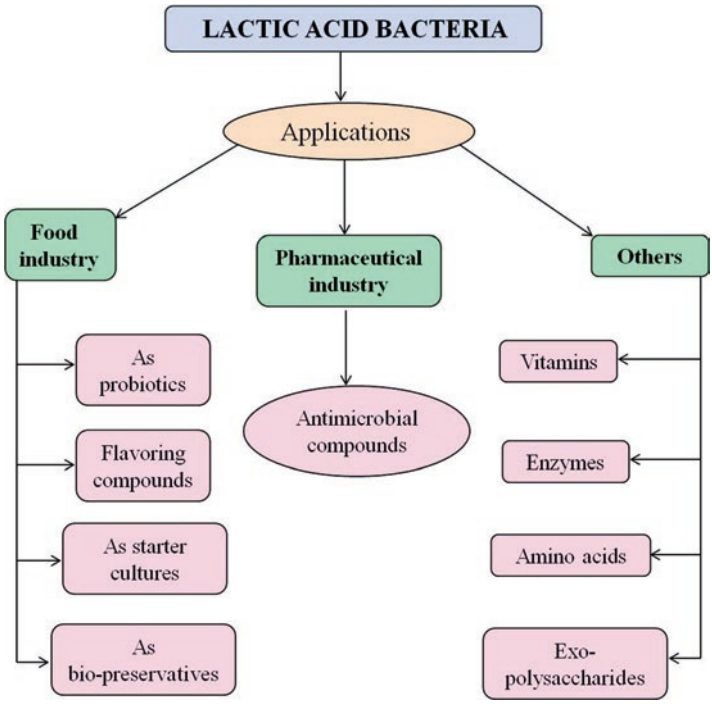

Fig. 6.1 Applications of LAB

Table 6.1 Bacterial species used as probiotics

Lactobacillus species	*Bifidobacterium* species	*Enterococcus* species	*Streptococcus* species
L. acidophilus	*B. bifidum*	*E. faecium*	*S. diacetylactis*
L. casei	*B. animalis*	*E. faecalis*	*S. cremoris*
L. paracasei	*B. infantis*		*S. salivarius*
L. rhamnosus	*B. thermophilum*		*S. intermedius*
L. johnsonii	*B. longum*		
L. delbrueckii ssp. *(bulgaricus)*	*B. adolescentis*		
	B. lactis		
L. brevis			
L. curvatus			
L. fermentum			
L. lactis			
L. plantarum			
L. reuteri			
L. cellobiosus			

bacteriocins, hydrogen peroxide, and organic acids. The action of LAB with the lymphoid cells in the gut and cells of the gastrointestinal tract increases the immune response of the gut against pathogens. Development of the function of mucosal barrier against ingested pathogens is done by increasing the production of mucus by the variation in the phosphorylation of proteins in tight junctions and cytoskeleton. The probiotic bacteria strive for the binding sites of epithelial layer with the pathogenic bacteria and inhibit the multiplication of strains like *E. coli* and *Salmonella*. Probiotic bacteria cooperate with the gut epithelial cells, directly (via compounds of cells like lipoteichoic acids, cell-surface polysaccharides, and DNA) or indirectly (by bioactive metabolite production). Probiotics influence the acquired and the innate immunity, thus having an important role in the human diseases. Probiotics remove the neoplastic cells of the host. Furthermore, the production of B-lymphocytes and antibody results in increase of the secretion of IgA and the vaccination response. Currently, probiotics prevent and reduce the harshness of respiratory infections, by increasing IgA in the bronchial mucosa (Reid 2016).

6.5 Applications of Probiotics in Human Health

There are several health benefits of probiotics:

Increase nutritional status of the individual
Increase vitamins, minerals, and trace elements availability to the body
Help in secretion of digestive enzyme, e.g., secretion of β-galactosidase
Prevention and treatment of diarrhea due to infection, traveler's diarrhea, acute viral diarrhea in children, diarrhea associated with overdose of antibiotics, and irradiation exposure diarrhea
Lowers down body cholesterol
Improvement of the immune system
Increase large intestinal motility that helps to relief constipation
Maintain mucosal integrity
Maintain intestinal microbes by antimicrobial activity
Decrease symptoms of lactose intolerance
Prevent food-borne allergies
Exhibit anticarcinogenic activities

An overview of health benefits of probiotic microorganisms has been given in Table 6.2.

6.5.1 Treatment of Diarrhea

Probiotics have a beneficial role in the prevention of diarrhea. It has been established that various probiotic strains like *L. rhamnosus* GG, *L. casei*, *L. reuteri*, *Bifidobacterium* spp., *S. boulardii*, etc., are useful in decreasing the duration and

Table 6.2 Probiotic strains and their health benefits

Probiotic strains	Health benefits	References
L. acidophilus NCFO1748	Constipation treatment, lowers fecal enzymes, prevents radiotherapy-related diarrhea	Giralt et al. (2008)
L. acidophilus LC1	Immune booster, maintains intestinal microflora balance, adjuvant for vaccines	Bernet et al. (1994)
L. acidophilus L1	Decreases total cholesterol level	Anderson and Gilliland (1999)
L. acidophilus LA5	Anti-infection, antidiarrhea, immune booster	Sadana et al. (2015)
L. rhamnosus GG	Anti-allergy, improves oral health	Schulz et al. (2015)
L. casei Shirota	Improves digestion, intestinal microflora reposition	Yadav and Shukla (2015)
L. gasseri	Reduction of fecal enzymes, intestinal tract survival	Pedrosa et al. (1995)
B. lactis	Enhances immune response, increases nonspecific immune functions	Mohan et al. (2008)
B. longum	Lowers serum concentration of total cholesterol, improvement of LDL/HDL cholesterol ratio, reduces lactose intolerance	Xiao et al. (2003)
B. adolescentis	Stimulates immune system	He et al. (2008)
B. animalis	Prevention of acute diarrhea	Shah (2007)
B. infantis	Increases anti-mutagenic activity	Hsieh and Chou (2006)
Streptococcus salivarius K12	Improvement of oral health, immune booster	Patel et al. (2015)
Enterococcus faecium SF68	Treatment and prevention of intestinal disorders	Hajela et al. (2015)
Saccharomyces boulardii	Immune booster	Patel et al. (2015) and Yadav and Shukla (2015)

severity of diarrhea (Isolauri 2004). The duration of acute diarrhea can be decreased by the oral administration of probiotics in children who are approximately of 1 day. The timing of administration is also very important for the action of probiotics. In antibiotic-associated diarrhea, *L. rhamnosus* GG and *S. boulardii* are effective in children or in adults who receive antibiotic therapy. The causative agent of antibiotic-associated diarrhea is *C. difficile*, which occurs after antibiotic treatment. It is an indigenous resident of a healthy intestine in low numbers. The antibiotic treatment may lead to disruption of healthy gut microflora, which results in increasing the number of *C. difficile*, which leads to diarrhea symptoms (Vasiljevic and Shah 2008; Ollech et al. 2016). Probiotic administration is very effective in the restoration of gut microflora. It is observed that *L. casei*, *B. longum*, *L. plantarum*, *B. breve*, *L. acidophilus*, *B. infantis*, *L. delbrueckii*, and *S. thermophilus* are very effective in the treatment of diarrhea caused by radiations. *L. casei* DN-114001 is very effective in the prevention of the radiation-induced diarrhea (Giralt et al. 2008). Probiotics are

also able to prevent traveler's diarrhea and diarrhea caused by rotavirus (Vanderhoof 2000). It inhibits rotavirus adherence by modifying glycosylation state of epithelial cell receptors by excreting soluble factors (Freitas et al. 2003). Probiotic microorganisms prevent the diarrhea caused by microbes either by competitive binding to gut epithelial cells or by producing antimicrobial bacteriocins such as nisin. Also the probiotic strains can modulate the innate immune response (Braat et al. 2004).

6.5.2 Eradication of *Helicobacter pylori* Infections

Probiotic strains produce a variety of antimicrobial substances such as organic acids (acetic acid and lactic acid), bacteriocins, hydrogen peroxide, fatty acids, and antifungal peptides. The organic acids lower the pH of the gastrointestinal tract, which has an inhibitory effect on pathogens. *H. pylori* is an intestinal pathogen which is associated with peptic ulcers, chronic gastritis, and gastric cancer (Plummer et al. 2004; Fallone et al. 2016). The lactic acid produced by *L. salivarius* was found to inhibit *H. pylori* growth in vitro (Aiba et al. 1998). Modulating the diet by adding the probiotics may reduce the bacterial load and inflammation (Khulusi et al. 1995). *L. casei* Shirota, *L. gasseri* OLL2716, and *L. johnsonii* La1 were found to reduce the colonization and inflammation caused by *H. pylori* (Felley et al. 2001, Sgouras et al. 2004). A study reported by a group of researchers concluded that regular intake of probiotic yogurt containing mixture of *L. acidophilus* La5 and *B. animalis* Bb12 may suppress the infection by decreasing the bacterial load (Wang et al. 2004).

6.5.3 Cardiovascular Diseases

Cardiovascular diseases include coronary artery diseases, stroke, hypertensive heart diseases, etc.

Cholesterol-rich diet increases the risk of coronary heart diseases by increasing the serum cholesterol level. Mann and Spoerry (1974) first time reported the decreased serum cholesterol level due to consumption of fermented milk. Regular intake of probiotics may decrease the concentration of serum cholesterol level. A group of researchers demonstrated the role of *L. plantarum*, *B. longum*, *E. faecium*, and *Propionibacterium freudenreichii* in hypercholesterolemia and cardiovascular diseases (Kiatpapan et al. 2001; Xiao et al. 2003; Nguyen et al. 2007).

6.5.4 Cancer Prevention

Some fermented foods such as yogurt, dahi, sauerkraut, kefir, kimchi, and fermented milk comprise of anticarcinogenic activities (Mohania et al. 2013, Kwak et al. 2014). Regular intake of probiotic yogurt containing *Lactobacillus* and *Bifidobacterium* could reduce the risk of cervical, bladder, and colon cancer

(Chandan and Kilara 2013). A study has been reported for the treatment of cancer by using kefir (Yanping et al. 2009). Fermented milk contains *L. acidophilus* which activates the immune system of the host and removes procarcinogens (Macouzet et al. 2009). A possible mechanism of cancer control by probiotic could be in the following ways: probiotics can cause inhibition of tumor cells and suppression of bacteria that produces such enzymes, which catalyze procarcinogen conversion to carcinogens. Also, they can destroy the carcinogens.

6.5.5 Prevention of Allergy

The prevention of atopic dermatitis (allergy) is the strongest evidence when some probiotics are supplemented to the newborns (up to the age of 6) and to pregnant mothers. Some specific probiotic strains are very operative for the treatment of the patients suffering from atopic eczema. *B. bifidum*, *B. lactis*, *E. coli*, and *L. lactis* have been reported for their beneficial roles in the treatment of eczema and food allergies (Niers, et al. 2009). Hong et al. (2010) reported anti-allergic effect of *L. kefiranofaciens* M1, isolated from kefir grains. *Lactobacillus* strain isolated from fermented kimchi has ability to modulate the balance of Th1/Th2 by producing interferons IL-12 and IFN-γ which reduce symptoms of food allergies and atopic dermatitis (Won et al. 2011; Koletzko 2016). Omega-3 fatty acid-rich fermented fish oil alleviates the allergic sensitization (Han et al. 2012).

6.5.6 Irritable Bowel Syndrome

An intestinal disorder with symptoms of belly pain, gas, diarrhea, and constipation is known as irritable bowel syndrome. *L. reuteri* may be involved in the improvement of symptoms after 1-week treatment. In summary, there is a data which suggests that some probiotics such as *B. infantis* 35624, *E. coli* DSM17252, and *B. breve* may be involved in the improvement of symptoms (Enck et al. 2009).

6.5.7 Inflammatory Bowel Disease

The major symptoms of inflammatory bowel disease (IBD) are diarrhea, abdominal pain, and gastrointestinal bleeding (Hanauer 2006). Ulcerative colitis and Crohn's disease are two categories of IBD, which are relapsing, remitting, and chronic diseases. Ulcerative colitis is a Th2-driven immune response characterized by production of interleukin (IL)-5, a pro-inflammatory cytokine. Further, Crohn's disease is Th1 immune response with a predominant increase in IL-12, interferon (IFN)-g, and tumor necrosis factor (TNF). Probiotic *L. acidophilus*, *E. coli* Nissle 1917, and *Bifidobacterium* have shown positive effects on ulcerative colitis (Imaoka et al. 2008). In vitro studies of IBD have shown that probiotic *L. rhamnosus* GG can modulate the host immune system by carrying out downregulation of TNF (Zhang

et al. 2005). Similarly, in vivo studies on animals indicated the beneficial role of *B. lactis* Bb12 in immune modulation and prevention of intestinal inflammation (Ruiz et al. 2005). A study revealed that fermented milk consumption could prevent the effect of ulcerative colitis (Ishikawa et al. 2003). In a similar study, *B. animalis* strains showed the reduction of IBD symptoms (Guyonnet et al. 2007).

6.5.8 Lactose Malabsorption

The condition of incomplete digestion of lactose (principle carbohydrate of milk) is known as lactose malabsorption. Due to deficiency of β-galactosidase enzyme, lactose does not completely break into glucose and galactose in the small intestine and passes to the large intestine (Shah 2015). The undigested lactose is fermented by the indigenous microflora of the large intestine, which results in production of short-chain fatty acids and gases (CO_2, CH_4, H_2). The gas production causes gastrointestinal disturbances such as abdominal pain, diarrhea, and flatulence (Granato et al. 2010). Probiotic microorganisms are extensively known to alleviate the symptoms of lactose malabsorption. Studies have been reported that *Bifidobacterium* may increase the production of β-galactosidase enzyme which can improve lactose digestion in the small intestine (Parracho et al. 2007). Furthermore, consumption of yogurt containing *B. animalis*, *L. delbrueckii* subsp. *bulgaricus*, and *S. thermophilus* could improve the gut microflora and reduce the symptoms of lactose malabsorption (Shah et al. 2013). Kefir is also an excellent source of β-galactosidase enzyme for persons suffering from lactose intolerance (Hertzler and Clancy 2003).

6.5.9 Immune System Modulation

Human immune system is a complex system which includes two types of immunity: innate (natural) and adaptive (acquired). The innate immunity of an individual is by birth and acts as the first line of defense to external stimulus. Natural killer cells are the key components of innate immunity and are involved in recognition and lysis of tumor cells, virus-infected cells, etc. On the other hand, the adaptive immunity is acquired through the lifetime of an individual. Both the immunities are key aspects of understanding the mechanisms of autoimmunity, allergy, vaccination, and carcinogenicity. The epithelial cells of the intestine remain in direct contact with gut microflora and interface with the immune system (Vasiljevic and Shah 2008). The epithelial cell-surface receptors recognize probiotics, and they beneficially affect the immune system (Isolauri et al. 2001). Dairy products containing probiotic bacteria could stimulate the mucosal immune system and increase the IgA+ cell count, which acts as a first line of defense (Lollo et al. 2013). Numerous studies reported immune system modulation by bifidobacteria. In a study, infants suffering with necrotizing enterocolitis were fed with breast milk containing *B. infantis* and *L. acidophilus*. As a result of probiotic intake, the severity of disease is reduced (Lin et al. 2005). A similar study revealed that fermented milk and yogurt contain some

nonbacterial components such as peptides and fatty acids which are produced during fermentation. These components were shown to modulate the immune system. Probiotic *L. plantarum* DSMZ 12028 and *Bacillus circulans* PB7 were also reported for immune modulatory effect (Cammarota et al. 2009).

6.6 Application in Animal and Plant Health

The microflora of the gastrointestinal tract of the animals is very important for the normal digestion. Probiotics attach to the mucus wall and adjust with the immune response of the host and then compete with the pathogenic microorganisms. Probiotics enhance the immune responses by the uptake of necessary nutrients for the body and are involved in the removal of pathogenic bacteria and increase of growth of nonpathogenic strains. The soil becomes more fertile by the presence of beneficial bacteria and fungi in the soil. Plant probiotic products could be used as biopesticides, biofetilizers, and plant stimulators. Probiotic bacteria also influence the hormonal equilibrium in plants (Berg 2009). Some commercial plant products that use probiotic cultures are Kodiak (*Bacillus subtilis* GB03), YiedShield (*B. pumilis* GB34), Rotex (*Phlebiopsis gigantea*), Cedomon (*Pseudomonas chlororaphis*), etc. (Song et al. 2012).

6.7 Conclusion and Future Perspectives

In this chapter, there is a brief knowledge of applications of different probiotic strains in human health. Effectiveness of probiotics could be improved by using the mixture of probiotics and prebiotics. For this purpose, *Bifidobacteria* can act as a valuable adjuvant for improvement of probiotic functionality. A person acquires his/her microflora at the time of birth from his/her mother's health as well as from surroundings. The presence of good microflora leads to good health conditions. External factors such as foreign microorganisms, diseases, and excess use of antibiotics may lead to disturbance of gut microflora. Probiotic microorganisms are able to restore the microflora which imparts various health benefits to the consumer. Fermented products such as yogurt, fermented milk, curd, kimchi, kefir, etc., are a good source of probiotics. In addition, researchers have reported various studies of probiotic applications in the treatment, prevention, and management of diseases. So, there is a requirement of designing new and improved form of probiotics for their applications in the field of food and health.

Effects of probiotics could be improved by the development of nano-encapsulated probiotics (the shelf life of the product can be enhanced by the encapsulation) by using nanotechnology applications. The WHO also suggested that probiotics will be the most important tool to fight against many infectious and noninfectious diseases in place of antibiotics which show many adverse effects like antibiotic resistance.

Antibiotic resistance cases can be treated by probiotics that is termed as microbial interference therapy. Thus, that time is not so far when probiotics will become the most commonly used therapeutic tool by medical personnels. Recent advancement in technology helps to isolate and colonize microorganisms to determine their specific therapeutic properties and uses. In countries like Japan, Europe, and Australia, probiotics and their related products currently occupy the largest sector in the food market. The European Commission has sponsored research projects for the safety and efficacy of the products.

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Ruby Yadav graduated in Biotechnology in 2010 from Kurukshetra University, Kurukshetra. She completed her M.Sc. (Microbiology) from Maharshi Dayanand University, Rohtak, India. She is currently pursuing Ph.D in Microbiology, Maharshi Dayanand University, Rohtak, India. Her current research interests are in Probiotics and Food Microbiology.

Pratyoosh Shukla is M.Sc. (Applied Microbiology Biotechnology) from Dr. H.S. Gour University, Sagar, India and Ph.D. in Microbiology and presently working as Professor and Head at Department of Microbiology, Maharshi Dayanand University, Rohtak, India. He was awarded with Indo-US Visiting research Professorship by American Society of Microbiology (ASM) in 2014. His current interests are Bioenergy, Enzyme technology and Protein bioinformatics.