Trends in Probiotics on Human Health and Industrial Application

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Abstract

Probiotics are living microorganisms present in gastrointestinal tract of human. They prevent the host from certain diseases and thus are beneficial for their hosts. This chapter will provide a comprehensive overview of probiotics, including their description, categorization, mode of action, therapeutic, and harmful effects. Moreover, different activities of probiotics, industrial processing, preservation, along with their dosage will be notified. The chapter also mentions various clinical trials to evaluate efficacy of probiotics. The nutritional properties, activities and applications of probiotics on the health of the host are going to be discussed. The benefits of taking probiotics on a daily basis will be discussed, as well as the importance of monitoring new adverse responses.

Keywords

Antibiotics · Nutrition · Prebiotics · Probiotics · Probiotic applications

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13.1 Introduction

The term "probiotic" comes from the Greek words "pro" and "bios", which mean "for life". The precise definition of probiotics by World Health Organization and Food and Agriculture Organization of the United Nations is "live microorganisms which when administered in adequate amounts confer a health benefit to the host". In general, probiotics are live microbial agents, consumed as a food supplement and sympathetically affect the microbial system of the host. Probiotic organisms require specific activities in order to provide maximal therapeutic impact by specifically encouraging the growth of specific bacterial species present in the host's colon (Mack et al. 1999; Sanders 2008). Microbiota is the collection of microorganisms, their genomes and metabolites, as well as the environment in which they reside in the human body. The gastrointestinal tract contains the greatest number of microorganisms that make up the microbiome. The oldest proposed probiotic benefit is microbiota balance. According to Metchnikoff it is "seeding" of the intestinal tract with innocuous lactic acid bacteria that destroy the growth of harmful proteolytic bacteria (Fuller 1991; Guarner 1998). Prebiotics, probiotics, synbiotics, and postbiotics are different forms of microbiota. Prebiotics are used as food by microorganisms, which has a positive influence on the host's health. Human milk oligosaccharides, lactulose, and inulin derivatives are examples of prebiotics that are currently available. Probiotics, on the other hand, affect the gut microbiota directly by specifically delivering beneficial microbes to the gastrointestinal system (Fuller and Gibson 1997). Bacteria from the genera *Lactobacillus*, *Bifidobacterium*, and *Streptococcus*, as well as yeast *Saccharomyces cerevisiae*, are the most commonly utilized probiotics. The notion of postbiotics is based on the knowledge that the microbiota's beneficial effects are mediated by metabolite secretion. Postbiotics are not regarded synbiotics in the literature, despite the fact that synbiotics are a combination of prebiotics and probiotics that have a favourable effect on the gut flora (Dunne et al. 2001).

The human body provides a nutrient-rich and stable home for live microbes in exchange for numerous benefits. The immune system is stimulated, food is better absorbed, digestion is enhanced, and germs are less likely to proliferate (Kesarcodi-Watson et al. 2008). The positive effects of the interaction between the microbiota and the gastrointestinal system can be seen locally as well as in distant organs. The "gut-organ axis" is the name given to this phenomenon (Juven et al. 1991).

It is the need of the hour to maintain a good health of probiotics because of its nutritional demand for all age group. Hence to maintain the health of the probiotics industrial processing plays vital role starting from its formulation to delivery and preservation.

13.2 Mechanism of Action

Despite the fact that the particular processes by which probiotics acquire their therapeutic effects are unknown. One of these ways explains why probiotics compete for cellular attachments by competing for adhesion sites. To colonize the

gastrointestinal system efficiently, many pathogenic organisms generally interact by forming a bond with the epithelium (Mishra and Lambert 1996). On the other hand, some strains of *Bifidobacteria* and *Lactobacilli* adhere to the epithelium and act as "colonization barriers", preventing pathogens from sticking to the mucosa. *Lactobacillus rhamnosus* strain GG and *Lactobacillus plantarum* 299v both inhibited the attachment of *Escherichia coli* to human colon cells (Schiffrin et al. 1995).

The "modification of the microbial flora through the creation of antimicrobial chemicals" is another possible method (Perdigon et al. 1995). Bacteriocins and other antimicrobial substances are produced by *lactobacilli* and bifidobacteria. Bacteriocins are the "compounds that are bacterially generated chemicals and comprise a bactericidal action along with biologically active protein moiety" (Vijayaram and Kannan 2018). The release of these chemicals by probiotic organisms alters the microflora in a positive way (Sütas et al. 1996). However, not all "*lactobacilli"* or "bifidobacteria" strains have antibacterial properties. The researchers observed that immune response can be stimulated by probiotics (Schiffrin et al. 1995). This immune reaction can be observed as a result of an increase in the secretion of Immunoglobulin-A (IgA), increased numbers of natural killer cells or enhanced macrophage phagocytic activity (Goldin 1998), if the IgA secretion increases, which reduces the number of pathogens in the stomach and improves the microflora composition (Pelto 1998). Because of their immunomodulatory properties, probiotics may aid with inflammatory bowel disease, food allergies, and vaccine adjuvants in addition to fighting intestinal and urogenital infections (Miele et al. 2009). Probiotics can compete for nutrients that infectioning microflora would eat (Vanderhoof and Young 1998). This condition arises with *Clostridium difficile*, a potential pathogen which depends upon monosaccharides for its growth (Fig. 13.1). The available monosaccharides are utilized by probiotic organisms, which inhibits *Clostridium difficile* (Wilson and Perini 1988).

Probiotic bacteria break down organic materials and enhance water quality in the "aquatic ecosystem". Exoenzymes produced by microbial cultures, including as amylase, protease, and lipase, aid in the degradation of unconsumed feed faeces in the pond. The ability of these enzymes to promote feed digestibility and utilization is a prospective application for them in animal nutrition. The mode of action of probiotics include (1) by producing bacteriocin-like chemicals (BLC), a disease can be inhibited, (2) in order to compete for attachment sites, (3) nutritional competition (4) pathogen enzymatic activity, immunostimulatory function, and nutritional benefits have all been altered i.e. improvement of feed digestibility and utilization (Gupta et al. 1998; Macfarlane and Cummings 1999).

13.3 Classification

The *Lactobacillus* and *Bifidobacterium* genera are the most common probiotic bacteria. Other bacteria and yeast, however, have probiotic characteristics. Different microorganisms used as probiotics currently are briefly described below.

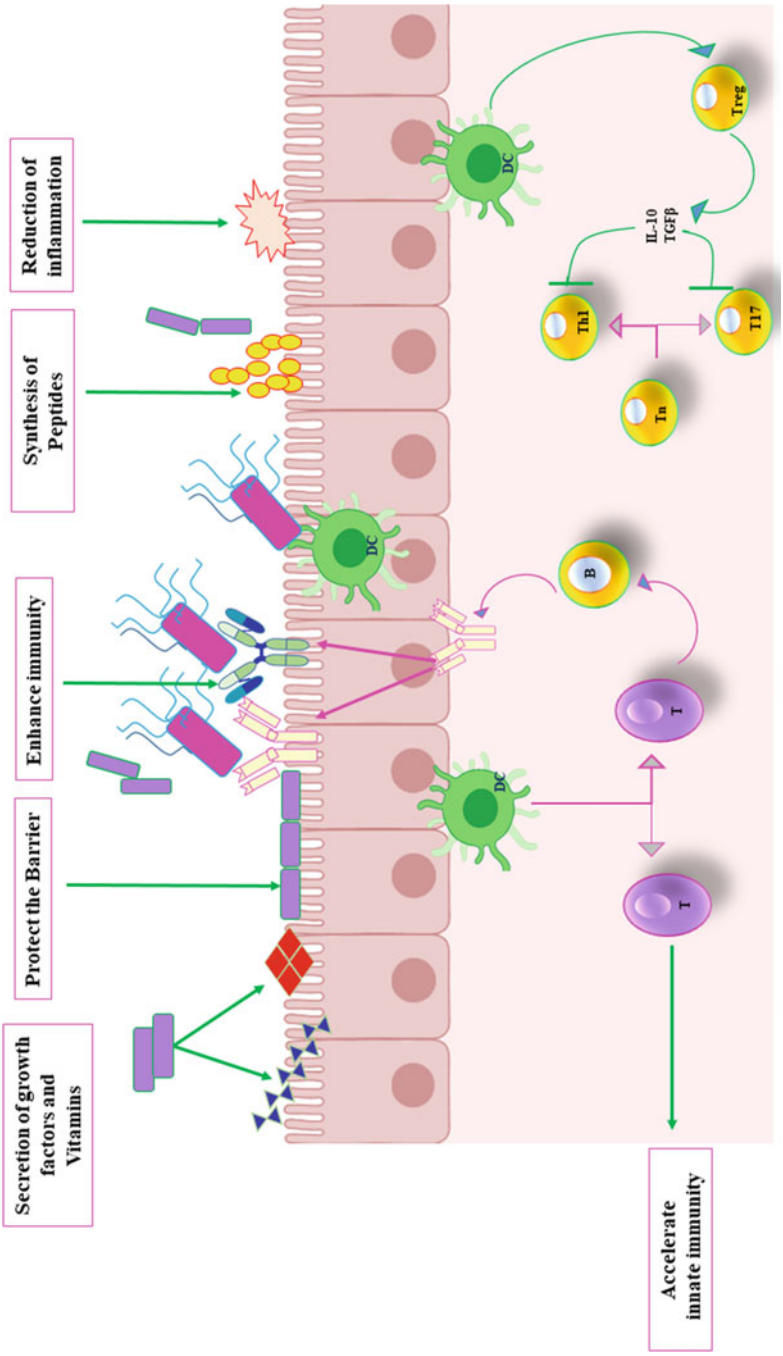

Fig. 13.1 Schematic diagram of different mechanisms includes the way of protection provided by probiotics to protect the epithelium and to enhance the immunity. Note: IEC: intraepithelial cells, DC: dendritic cells, T: T cells, B: B cell, Th: T helper cell, IL: Interleukins, TGFβ: Transforming growth factor beta. Treg: Regulatory T cells

13.3.1 *Lactobacillus* Species

Lactobacillus is a Gram-positive bacteria that produces lactic acid and drives anaerobes out of the human gastrointestinal tract (Vanderhoof and Young 2004). The *lactobacillus* denotes the ability of bacterium to produce lactic acid. *Lactobacilli* are used as probiotics therapeutically. They're also known as "friendly bacteria", and they're utilized to recolonize parts of the body in order to provide nutritional benefits including promoting growth factors and increasing mineral absorption (Bruce and Reid 1988; McGroarty 1993). It also aids in the regulation of the mucosal barrier as well as the reduction of intestinal permeability (Madsen et al. 1999).

Changes in the usual flora allow pathogenic organisms to colonize, causing symptoms such as diarrhoea, cramps, and, in rare cases, pseudomembranous colitis (PMC), which is caused by *C. difficile* (Shornikova et al. 1997). Most of the research studies depicted that combination of probiotics and *lactobacillus* cannot be prescribed at a time as this combination could be harmful by reducing the normal flora of the human body (Reid et al. 1990; Sanders and Klaenhammer 2001). *Lactobacilli* that create hydrogen peroxide have antibacterial effects against the vaginal pathogen *Gardnerella vaginalis*, and their presence in the vagina has been linked to lower rates of bacterial vaginosis and trichomoniasis (Sullivan 2003). *Lactobacilli* create lactic acid, which lowers vaginal pH and prevents pathogen growth (El-Nezami et al. 1998; McIntosh et al. 1999).

Lactobacilli and other probiotics have been shown to be effective in the fight against cancer in some trials. *Lactobacilli*, particularly *Lactobacillus plantarum*, have also been shown to reduce the severity of chemotherapy-induced enterocolitis in previous studies (Goldin et al. 1996). *Lactobacillus bulgaricus* and *Lactobacillus sporogenes*, according to other studies, show hypolipidemic and anti-atherosclerotic properties. According to some clinical evidence, it lowers total and low-density lipoprotein cholesterol while having no effect on high-density lipoprotein cholesterol (HDL) (Mastromarino et al. 2009). Cholesterol is reduced by fermented dairy products like yoghurt and acidophilus milk. *Lactobacilli* and other probiotic bacteria bind bile acids to cholesterol and enhance fatty acid production in the gut, lowering circulatory fatty acid concentrations by blocking hepatic cholesterol synthesis or transferring cholesterol from the plasma to the liver (Mao et al. 1996).

13.3.2 *Bifidobacterium* Species

Bifidobacterium is an anaerobic, Gram-positive, non-spore-forming, pleomorphic bacteria. Lactic and acetic acids are produced by the bacteria in the *Bifidobacterium* genus, as by-products of utilization of glucose (Losada and Olleros 2002). *Bifidobacterium longum subsp. longum* BB536 was the first probiotic bacteria isolated from the intestinal system of healthy newborns, according to reports *Bifidobacteria*, in combination with *Lactobacillus* species and the probiotic yeast *Saccharomyces boulardii*, appear to reduce the negative impact of *Helicobacter* infection but not compliance. Furthermore, combining *Bifidobacterium infantis* with

Lactobacillus acidophilus appears to reduce Necrotising enterocolitis (NEC)-related mortality in critically unwell neonates (Oberhelman et al. 1999).

13.3.3 *Bacillus* Species

Due to the property of lactic acid production, *Bacillus coagulans,* a Gram-positive rod, is often misclassified as lactic acid bacteria, i.e. *lactobacillus*. In fact, commercial items containing *B. coagulans* are promoted as "spore-forming lactic acid bacteria" or *Lactobacillus sporogenes*. The property of forming spores differentiate these species from *lactobacillus*. *B. coagulans*, on the other hand, is not found in the typical human flora, but it is utilized therapeutically in the same way as *Lactobacillus* and *Bifidobacterium* are. Every probiotic must be capable to persist and colonize in the intestinal mucosa, in order to be effective for restoring normal flora and prevent pathogenic colonization. After ingesting the spores by human, it is unknown what happens to the spore and Bacillus spore is capable of germinating in the intestinal tract or if colonization occurs (Cremonini et al. 2002).

13.3.4 *Saccharomyces* Species

Saccharomyces cerevisiae, often known as *S. boulardii,* is a nonpathogenic yeast strain. It is a diarrhoea medication and used to treat and prevent diarrhoea. In Indochina, *S. boulardii* was isolated from the skins of tropical fruits. Since ancient times, the indigenous people of Indochina have employed these fruit skins to prevent and treat diarrhoea (Hoyos 1999).

13.4 Probiotics Activities

13.4.1 Probiotics in Antibiotics

Probiotics aid in the stimulation of the immune system, the prevention of allergies, and the reduction of cholesterol levels (Duc et al. 2004). Microbial drugs are used as chemotherapeutic agents.

The discovery of actinomycin as an anticancer agent led to a foray into the world of microbes. The medications that demand special attention are actinomycin D, anthracycline, bleomycin (mithramycin, streptozotocin, and pentostatin), calicheamicin, and taxol epothilones. Actinomycin, a Streptomyces antibiotic, was found to be effective in treating children with Wilms tumour (Szajewska et al. 2001).

13.4.2 Probiotics in Antibacterial Activity

Probiotics' therapeutic benefits have increased their ability to boost the gut's immunological and nonimmunological defence barrier, improved intestinal penetrability, and altered gut microbiota. From black tiger shrimp (*Penaeus monodon*), 12 diverse intestinal bacterial colonies were isolated. Among these, the bacterium *Bacillus subtilis* was investigated and classified as having antagonistic qualities against three pathogenic bacterial strains: *Vibrio alginolyticus*, *Vibrio harveyi*, and *Vibrio vulnificus* (Buts 2005; Ringø et al. 2018).

A number of microorganisms have been identified as being pathogenic to aquatic animals. Six Gram-negative rods (*Proteus*, *Citrobacter*, *Aeromonas*, *Pseudomonas*, *Flavobacterium*, *Chromobacterium*) and three Gram-positive cocci (*Micrococcus*, *Streptococcus*, and *Staphylococcus*) have been identified (Rengpipat et al. 1998).

13.4.3 Dosage

The amount of living organisms contained in a probiotic product determines the dosage. Clinical investigations have shown that utilizing between 10^7 and 10^{11} sustainable bacteria per day can produce effective results (Chauhan and Singh 2019). Remarkably, it appears that a dairy product requires 100 times less sustainable bacteria than a freeze-dried supplement to achieve comparable amounts of live bacteria in the lower colon (Mahajan et al. 2013). Dairy products operate as an ideal transportation medium for bacteria, allowing them to survive longer in the upper gastrointestinal tract (Vijayaram and Kannan 2018).

13.4.4 Therapeutic and Adverse Actions

Probiotics are living bacteria that provide health advantages in addition to providing needed nourishment. Probiotic bacteria have a wide range of beneficial effects, including improved lactose intolerance symptoms, lower blood cholesterol, anticancer properties, constipation relief, and relief from vaginitis. Many strains of *Lactobacillus* such as *L. rhamnosus*, *L. acidophilus*, and *L. casei* and strains of Bifidobacterium like *Bifidobacterium longum*, *B. infantis*, *B. adolescentis*, and *B. breve* exhibited noteworthy suppression of colon tumour (Posteraro et al. 2005).

Although probiotics are extensively used and side effects are uncommon, certain studies have found that *Lactobacillus* GG causes liver abscess, sepsis, and endocarditis in people with severe disease (Zocco et al. 2006).

13.4.5 Drug Interactions with Probiotics

Antibiotics and alcohol do not affect Lactobacilli and *Bifidobacteria* (Hatakka 2001). Despite the fact that studies suggesting the organism has no effect on

antibiotic activity, *L. acidophilus* strains can impact the metabolism of sulfasalazine and chloramphenicol palmitate (Khalighi et al. 2016).

13.5 Applications

Probiotics control pathogens through different mechanisms and are used as an alternative to antibiotics (Segarra-Newnham 2007). Probiotics were used for nutritional purpose in the human and animals (Elahi et al. 2008) but now they are being used in aquaculture also. Probiotics provide a number of advantages, including a moderate rejection of harmful bacteria as a source of nutrition, enzymatic engagement in digestion, and direct application of dissolved organic material assisted by the bacteria. Probiotics also help to strengthen the immune system's response to harmful bacteria (Whelan and Myers 2010).

13.6 Probiotics and COVID 19

Evidences supported the role of probiotics' in immune system regulation, also proposed its decisive role in viral infections. Probiotics taken as supplements might decrease the severity of COVID-19 and also reduced its morbidity and rate of mortality. Probiotics can prevent cytokine storms by boosting innate immunity and preventing adaptive immunity from overreacting. Effective treatment will reduce the pandemic's impact on people's lives and economies around the world. Thus, probiotic supplementation in high-risk and critically ill patients, as well as frontline health professionals, may help to bind the pathogen and flatten the COVID-19 curve.

13.6.1 Updates on Industrial Probiotics

These days application of the probiotics have been accelerating a lot, research and development of the probiotics industry now focusing towards using multiple strain of the probiotics such as *S. thermophilus*, *E. faecium*, *B. breve*, *B. infantis*, *B. longum*, *L. acidophilus*, *L. plantarum*, *L. casei*, and *L. delbrueckii* subsp. *bulgaricus* for enhancing the body immunity and protecting the body from various pathogenic virus, bacteria, fungus, etc. by converting the protein to bioactive peptides and other powerful metabolites.

Apart from the normal probiotic yoghurt, most of the industries are now working on making flavoured probiotics. Some probiotics brands are also focusing to enhance the nutrient of the probiotics by adding some prebiotics. Some industries such as Truebasics, Bifilac, Lee-Biotic, Biovir, Hmf Forte, Yakult, and Lactobact are adding the medicinal plant extracts, fruits, and flower extract also to the probiotics, for example, to the milk and yoghurt as mentioned in the below flow chart (Fig. 13.2).

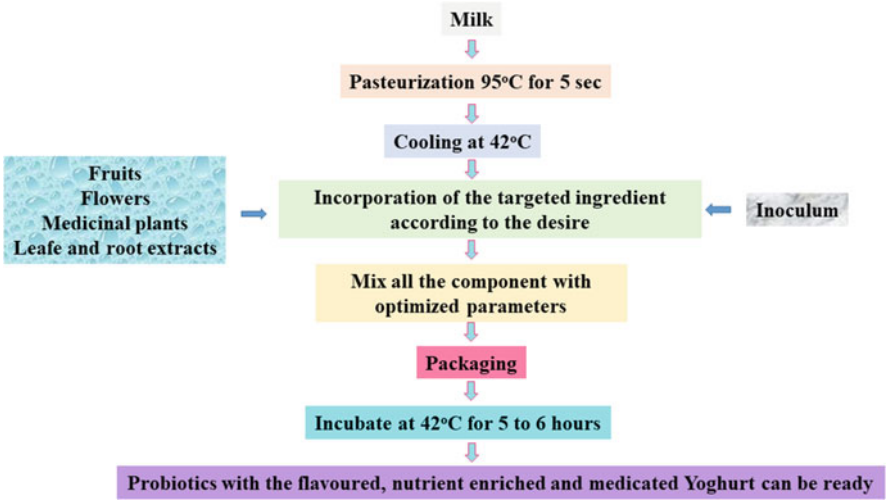

Fig. 13.2 A probiotic dairy product with added medicinal plant extracts

Nowadays some experiments proven the fruitful journey from home probiotics to industrial probiotics was proven as a best candidate for the treatment of ulcerative colitis, cancer, COVID-19, irritable bowel syndrome and many more.

13.7 Conclusion

Probiotics is a governing body of our digestive system which leads to every metabolic activity very smooth. As probiotics are very helpful for human health and curing most of the disease, now the markets are demanding more probiotics in different form of food. Hence more research is highly essential for formulation of novel probiotics and enhancement of shelf life period of the probiotics in the food.

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