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Probiotics and Human Health: An Overview

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Abstract
Probiotics are beneficial bacteria that, when consumed in adequate amounts, can promote a healthy microbiota and improve various bodily functions. These microorganisms can be found in fermented foods like yogurt, kefir, and sauerkraut, as well as in dietary supplements. The human body contains trillions of microorganisms, collectively known as the microbiota, which play crucial roles in maintaining human health. However, disruptions to the microbiota can lead to dysbiosis, a state of imbalance that has been linked to several health problems. Probiotics can help restore and maintain a healthy microbiota by introducing beneficial bacteria into the gut. Research has shown that probiotics can alleviate symptoms of digestive problems like diarrhea, constipation, and irritable bowel syndrome (IBS). They can also have a positive impact on the immune system by enhancing the activity of immune cells and increasing the production of antibodies. Probiotics have also been studied for their potential to improve allergies, eczema, and respiratory infections. However, more research is needed to determine the optimal strains, doses, and formulations of probiotics for specific conditions. Conclusively, probiotics have significant potential to improve human health by promoting a healthy microbiota and supporting various bodily functions. However, further research is necessary to fully understand their benefits and to develop evidence-based guidelines for their use.

Keywords: Probiotics, *Lactobacillus*, Diseases, health purposes, gut

Introduction

People around the world are becoming increasingly aware of the link between nutrition and good health. This has stimulated an increase in research to identify foods and food ingredients that provide specific consumer benefits. These efforts have led to the emergence of probiotic products called functional foods. This includes foods containing phytochemicals, fiber, structured lipids, bioactive peptides, polyunsaturated fatty acids, etc. Prebiotics, probiotics and synbiotics fall into this category (Holzapfel & Schillinger, 2002). There are many definitions of the term probiotics, but the widely accepted definition is Fuller's (Sayes et al., 2018). According to him, "probiotics" are live microbial dietary supplements that have a beneficial effect on the host by improving the microbial balance in the gut. The term 'probiotics' is derived from the Latin word 'pro' and the Greek word 'bio' meaning 'for life' and is related to the term 'probiotics' (Sayes *et al.*, 2018).

Probiotics are defined by WHO/FAO (2001) as "live microorganisms that, when consumed in adequate amounts, confer a health benefit on the host". The most commonly used probiotic strains belong to the heterogeneous group of *Lactobacillus* (LAB), *Enterococcus, Streptococcus, Leuconostoc, Lactococcus, Pediococcus, Bifidobacterium,* and the yeast *Saccharomyces boulardii*. Lactic acid bacteria (LAB), especially *Lactobacillus sp.*, have received a lot of attention due to their "generally recognized as safe" (GRAS) status and health-promoting effects as probiotics (Zieliunska *et al.*, 2015). The nutritional benefits of probiotics include their role in improving bioavailability of various minerals, protein digestibility, and synthesis of vitamins in yoghurt (Radulovic *et al.*, 2010). Reported therapeutic benefits of probiotic consumption include lipid and serum cholesterol lowering, improved immune function, and antimicrobial properties (Lee *et al.*, 2014). Probiotics have been found to be effective in treating several gastrointestinal disorders (Marteau *et al.*, 2001).

It is clear that a number of definitions of the term 'probiotic' have been used over the years but the one derived by the Food and Agriculture Organization of the United Nation and World Health Organization FAO/WHO (2001) and endorsed by the international Scientific Association for Probiotics and Prebiotics (Reid *et al.*, 2003), best exemplifies the breadth and scope of probiotics as they are known today: 'live microorganisms which, when administered in adequate amounts, confer a health benefit on the host. While this definition retains historical elements of the use of organisms for health purposes, it does not limit the application of the term to oral probiotics that affect the gut (Reid *et al.*, 2003).

Despite these numerous theoretical definitions, a practical question arises as to whether a particular microorganism can be considered a probiotic. Several stringent criteria have been proposed. Havenaar and Huis (1992), for example, proposed the following parameters for selecting probiotics: Absolute host safety, resistance to gastric acid and pancreatic secretions, adhesion to epithelial cells, antibacterial activity, inhibition of adhesion of pathogenic bacteria, evaluation of resistance to antibiotics, resistance to food additives, and stability in food matrices.

The probiotics in use today were not selected based on all of these criteria, but the most commonly used probiotics are *Lactobacillus, Bifidobacterium* and *Streptococcus* (S. *thermophilus*), the first two are known to resist gastric acid, bile salts, and pancreatic enzymes, adhere to the colonic mucosa, and readily colonize the intestinal tract (Fioramonti *et al.,* 2003). The main sources of probiotics are fermented non-digestible carbohydrate compounds, dietary supplements, dairy-based compounds, non-dairy fermented foods, and non-gut sources. Many people use living cells containing food to improve nutrient quality, micronutrient bioavailability, strengthen the host's anti-oxidative defense mechanisms, and slow aging (Naeem *et al.*, 2013; Monica *et al.*, 2016).

Human Health Properties of Probiotics

Since humans began using fermented milk as food, LAB containing various types of *Lactobacillus* and *Enterococcal* species have been consumed daily. The effects of probiotics vary, especially between strains. The effects shown with one strain cannot be extrapolated specifically to other strains, and each individual strain of probiotic bacteria has its own health benefits (Ravinder *et al.*, 2012). Probiotics are very important and have uses in fighting various types of microbial infections, it can also be used to improve human health, control infections, treat and manage disease (Roswitha *et al.*, 2013) as found below:

Anti-allergic Properties

Allergies are the immune system's erroneous reaction to (possibly harmless) particles. Probiotics treat allergies by healing the damaged digestive system. This reduces inflammation, stabilizes the immune system and strengthens the intestinal lining. Allergies are hypersensitivity reactions caused by immunological mechanisms. Probiotics alter the structure of antigens, reducing their immunogenicity, intestinal permeability and the formation of pro-inflammatory cytokines. This is of paramount importance for patients with various allergic diseases (Shyamala *et al.*, 2016). Manoj *et al*. (2012) reported that *Lactobacillus* GG and *L. rhamnosus* GG play an important role in relieving the symptoms of food allergy as well as reducing the risk of developing allergic diseases.

Blood Pressure Regulation

Probiotics and their products have also been shown to improve blood pressure through mechanisms such as improving total and low-density lipoprotein cholesterol levels (Patel *et al.*, 2010; Guo *et al.*, 2011). Interestingly, probiotic supplementation may be beneficial in lowering blood pressure in hypertensive conditions. *Lactobacillus bulgaricus, Bifidobacterium breve, Bifidobacterium longum, Streptococcus thermophilus, Lactobacillus delbrueckii ssp. bulgaricus, Lactobacillus helveticus, Saccharomyces cerevisiae, Lactobacillus rhamnosus GG, Lactobacillus casei, Lactobacillus acidophilus, Lactobacillus rhamnosus* and *Lactobacillus kefiri* are commonly used to treat hypertension (Rerksuppaphol, 2015; Golnaz *et al.,* 2017).

Treatment of Inflammation and Bowel Disease

Incorporation of probiotic bacteria has the ability to stabilize the intestinal mucosal immune barrier by reducing the formation of local pro-inflammatory cytokines. Probiotics are used to treat inflammatory bowel diseases such as ulcerative colitis, Crohn's disease, and pouchitis. Possible mechanisms include inhibition of proliferation or epithelial attachment and invasion by pathogenic bacteria, production of antibacterial agents, enhancement of epithelial barrier function, and immunomodulation. The effects of probiotics can be both strain- and dose-dependent (Momir and Maja, 2014).

Treatment of Genitourinary Infections (Bacterial vaginities)

Bacterial vaginosis is an abnormal vaginal condition characterized by vaginal discharge, resulting from an overgrowth of atypical bacteria within the vagina. A UTI is an infection of the kidneys, ureters, bladder, or urethra. These are the structures through which urine passes before being expelled from the body. Genitourinary infections are caused by changes in the vaginal environment with reduced or absent concentrations of *lactobacilli*. *Lactobacillus* is the major microbial factor that determines the presence, growth, colonization, and persistence of non-endogenous microorganisms within the vagina. As the genus *Lactobacillus sp*. count decreases, so does protection against urinary tract pathogens (Rukshana *et al.*, 2017; Lorenzo *et al*., 2017). It has also been suggested that *Lactobacilli* produce biofilms covering urogenital cells. The use of lactic acid bacteria for bacterial vaginosis is supported by positive results from clinical studies. Probiotic capsules such as *Lactobacillus rhamnosus*, *Lactobacillus crispatus*, *Lactobacillus gasseri*, *Lactobacillus vaginalis*, *Lactobacillus acidophilus*, *Lactobacillus reuteri*, and *Streptococcus thermophilus* may help prevent recurrent bacterial vaginosis (Rukshana *et al.*, 2017; Lorenzo *et al.*, 2017). The main mechanisms by which *lactobacilli* exert protective functions in urogenital health management are:

- Stimulation of the immune system.
- Competition with other microorganisms for nutrients and for adherence to the vaginal epithelium, urinary and vaginal tract cells.
- Reduction of the vaginal pH by the production of organic acids, especially lactic acid.
- Production of antimicrobial substances and competitive

exclusion Inhibitor production, such as bacteriocins, and hydrogen peroxide (Rukshana *et al*., 2017; Lorenzo *et al*., 2017).

Treatment of Liver Disease

The intestinal lumen-resident microbiota plays an important role in hepatocyte function. Changes in the types and numbers of microorganisms that inhabit the intestinal tract can lead to severe and harmful liver dysfunction, such as cirrhosis, non-alcoholic fatty liver disease, alcoholic liver disease, and hepatic encephalopathy. Probiotics have been used as a novel therapeutic strategy for liver disease with mechanisms to modulate, restore, and alter gut microbiota and immune function (Lunia *et al*., 2014). By strengthening the intestinal barrier, probiotics block microbial entry into the bloodstream and ultimately the liver, thus helping to treat chronic liver disease (Cesaroa *et al.*, 2011).

Cholesterol Assimilation

Probiotic strains, especially lactic acid bacteria, play a prominent role in cholesterol levels by lowering mechanisms. Using probiotics can directly or indirectly lower cholesterol levels. Direct mechanisms include inhibition of denovo synthesis or decreased intestinal absorption of dietary cholesterol. Reducing dietary cholesterol retention can be done in three ways: anabolic, binding and degradative. Probiotic strains absorb and digest cholesterol, they can attach to cholesterol particles and break down cholesterol into catabolic products. Cholesterol levels can be lowered indirectly by deconjugating cholesterol to bile acids, thereby reducing the aggregate pool (Bordoni *et al.*, 2013). Hypercholesterolemia (elevated cholesterol levels in the blood) is considered a major risk factor for developing coronary heart disease. Therefore, lowering serum cholesterol levels is important for disease prevention. The ability of LAB isolates to clear cholesterol was assessed by *invitro* and *invivo* mechanisms. *Lactobacillus* pentosus LP05, *L. brevis* LB32, *L. reuteri* and *L. plantarum* have been reported to be potent tools (Naheed *et al.*, 2015).

Anticarcinogenic Properties

It was reported that introduction of *L. acidophilus* into diet reduces the incidence of chemically induced colon tumors in rats (Goldin and Gorbach, 2002). It was also later suggested that diet and antibiotics could reduce carcinogen formation in the colon and reduce chemically induced tumors (Majid *et al.*, 2015; Sayes *et al.*, 2018). These effects appear to be mediated through the gut microbial community. A possible mechanism for these anticancer effects is through inhibition of gut bacterial enzymes that convert procarcinogens to more proximal carcinogens (Kumar *et al.*, 2011). This approach can be expanded in the future by testing probiotics for their ability to inhibit the growth of organisms normally found in the flora that have high activities of enzymes such as b-glucuronidase (Sayes *et al.*, 2018), nitroreductase, azoreductase, and b-glycosidase or the capability for nitrosation.

The sixth most common cancer in the world is the hepatitis B virus. Eating food contaminated with aflatoxin is also thought to cause liver cancer. *Aflatoxin* B1 (AFB1) causes characteristic genetic changes in the p53 tumor suppressor gene and rat proto-oncogene. Some probiotic bacterial strains have been shown to bind and neutralize AFB1 in *vivo*, reducing the bio absorption of toxins from the gut (Haskard *et al*., 2000; Kumar *et al.*, 2011). Addition of the probiotic *Bifidobacterium longum* to the diet of rats has been shown to exert potent antitumor activity in the colonic mucosa by reducing the expression levels of ras-p21 expression and cell proliferation. (Carlos *et al.*, 2010; Miriam *et al.*, 2018).

Probiotics also reduce fecal levels of enzymes (glycosidases, β-glucuronidase, azoreductase, and nitroreductase) and secondary bile salts, harmful mutagens that may contribute to the development of colon cancer. Normal gut microbiota can influence carcinogenesis by producing enzymes (glycosidases, β-glucuronidases, azoreductases, and nitroreductases) that convert procarcinogens to active carcinogens (Goldin et *al*., 1990., Pedrosa *et al*., 1995). Supplementation with *Lactobacillus acidophilus* and *L. casei* helped reduce levels of these enzymes in humans (Lidbeck *et al*., 1991). Administration of *Lactobacillus GG* determined up-regulation and down-regulation of 334 and 92 genes through (intracellular adhesion molecules and integrins), cell adhesion (cadherins), and signal transcription and transduction, respectively (Caro *et al*., 2005). In mice, these bacterial enzymes were suppressed by administration of *Lactobacillus GG* (Drisko *et al*., 2003). Lactic acid bacteria inhibit colon cancer by enhancing the host immune response, altering the metabolic activity of the intestinal microbial community, binding and degrading carcinogens, producing antimutagenic compounds, and altering the physicochemical conditions within the colonic intestine. Several possible mechanisms have been proposed (Hirayama and Rafter, 2000; Kumar *et al*., 2011). Oral administration of LAB has been shown to be effective in reducing chemical carcinogen-induced DNA damage in the gastric and colonic mucosa of rats (Li & Li, 2003).

In the Comet assay, *Lactobacillus acidophilus, Lactobacillus gasseri, Lactobacillus confussus, Streptococcus thermophilus, Bifidobacterium breve*, and *B. longum* were antigenotoxic to N'-nitro-N-nitrosoguanidine (Carlos *et al*., 2010; Sayes *et al*., 2018). These bacteria were also protected from genotoxicity by 1, 2-dimethylhydrazine (DMH). Acetone extracts of metabolically active *L. acidophilus* cells and cultures prevented MNNG-induced DNA damage, whereas heat-treated *L. acidophilus* was not antigenotoxic. Azomethane-induced colon tumorigenesis was also suppressed, along with colonic mucosal cell proliferation and decreased tumor ornithine decarboxylase and ras p21 activity (Hirayama and Rafter, 2000).

There was a report on the anti-tumorigenic activity of the prebiotic inulin supplemented with oligofructose in combination with the probiotics *Lactobacillus rhamnosus* and *Bifidobacterium lactis* in an azoxymethane (AOM)-induced colon carcinogenesis rat model (Femia *et al*., 2002). Other *lactobacilli* have also shown their ability to reduce the risk of colon cancer. However, the relationship between enzyme activity and cancer risk needs further investigation.

Management of Gastrointestinal Infection (GIT)

Probiotic microorganisms such as *Lactobacillus* and *Bifidobacterium* (Kerry *et al*.,2018) play a major role in the prevention of gastrointestinal infections. This is affected by the production of lactic acid, adhesion to host cells, elimination or reduction of pathogens and hydrogen peroxide. Production of bacteriocins that help prevent the growth of pathogenic microorganisms and enhance the body's natural protective immunity (Maldonado *et a*l., 2018). *Bifidobacterium adolescentis* and *Bifidobacterium pseudocatenulatum* produce B group vitamins (B1, B2, B3, B6, B8, B9, and B12) which strengthen the immune system, stimulate the formation of organic acids and amino acids. Probiotics produce enzymes such as esterases, lipases, coenzymes A, Q, NAD and NADP. Some metabolites of probiotics can also exhibit antibiotic effects (Nova *et al*., 2007). Probiotic microorganisms also produce immunoglobulins, enhance the activity of macrophages, stimulate γ-interferon production, and promote the innate and acquired immune system through metabolites, cell wall components, and DNA recognized by specialized host cells, strengthens the immune system (Oelschläger, 2010).

Diarrhea Control

Probiotics play a major role in preventing diarrhea in both adolescents and adults. Probiotic bacteria such as *Lactobacillus GG*, *Bifidobacteria spp*., *Lactobacillus reuteri*, and *S. boulardii* have been used to combat diarrhea. The above bacteria have the ability to suppress traveler's diarrhea by producing bacteriocins (NISIN) and preventing diarrhea-carrier microbes from binding to epithelial cells (Amara, 2015). Probiotics can prevent diarrhea by protecting the host from toxins. Markowiak (2017) reported that administration of *Saccharomyces boulardii* yeast to patients with acute watery diarrhea resulted in healing and reduced discomfort for two consecutive months.

Control of *Helicobacter pylori* Infection

Lactobacillus salivarius produces large amounts of lactic acid and inhibits the growth of *Helicobacter pylori* in vitro. Probiotic bacteria have been reported to be capable of inhibiting gastric colonization and activity of *H. pylori*, associated with peptic ulcer disease, stomach cancer, and gastritis. *L. salivarius* also inhibited *H. pylori* colonization in in vitro studies and in mice. Also, *H. pylori* infection can be modulated by probiotics, which improve eradication rate, tolerability, and response to several antibiotics used to treat *Helicobacter pylori* infection (Amara, 2015). In fact, probiotic treatment not only eradicates *Helicobacter pylori*, it can actually reduce the number of bacteria (Halvorsen *et al*., 2009).

Blood Cholesterol Control

Cholesterol plays an important role in the body, among other things in the synthesis of steroid hormones, but excessive cholesterol levels in the blood increase the risk of heart disease three times higher than those with normal blood lipid levels (Goh, 2013). Studies have shown that consumption of dairy products containing probiotics lowers blood cholesterol levels (Ishimwe *et al*., 2015). In a 12-week randomized trial by Daliri and Lee (2015), *L. acidophilus* CHO-220 and inulin were administered to 32 hypercholesterolemic men and women, total plasma cholesterol and low-density lipoprotein (LDL) cholesterol were reduced by 7.84% and 9.27% respectively.

Possible mechanisms of cholesterol lowering include the production of short-chain fatty acids (SCFAs), the binding action of cholesterol to the probiotic cell surface, deconjugation of bile-by-bile salt hydrolase and incorporation of cholesterol molecules into the probiotic cellular membrane. *Bifidobacterium* and *Lactobacillus* species produce bile salt hydrolase (BSH), which is important for the hydrolysis of amide bonds between bile acids and their conjugates (Lee, 2015). Studies show that BSH hydrolyzes conjugated bile acids to form cholesterol-free primary bile acids. This primary bile acid is not efficiently absorbed from the intestinal lumen and is excreted in the feces, thereby lowering cholesterol (Huang *et al*., 2013). *Sterolibacterium denitrificans* produces the enzyme cholesterol dehydrogenase, which helps convert cholesterol to cholest-4-en-3-one and then to coprostanol, which is subsequently excreted in the faeces (Ooi & Liong, 2010).

Control of Lactose Intolerance

Lactose is a carbohydrate derived from mammalian milk. Lactose intolerance or malabsorption may result from insufficient or absence of lactase to convert lactose to glucose and galactose in the small intestine (Barling, 2012), resulting in diarrhea, bloating, and abdominal pain. Probiotic bacteria such as microbial *lactosidases* in *L. acidophilus* milk and yogurt are important for lactose digestion and absorption in lactose-intolerant patients (Daliri, 2015).

Regulation of Pathogenic Activity

Eating pathogen-contaminated food distorts the intestinal flora, causing food poisoning and other bodily disorders. Therefore, the use of probiotics can help prevent the growth of such pathogens and modulate side effects such as toxins (Markowiak, 2018). Probiotics have the ability to inhibit the growth of pathogens such as *Salmonella enterica, Serovar typhimurium, Clostridium perfringens, Staphylococcus, E. coli,* and some species of *Shigella* (Saint-Cyr *et al*., 2018). Production of lactic, propionic, acetic, and butyric acids from the short-chain fatty acids (SCFAs), acetaldehydes, hydrogen peroxide (H_2O_2) by probiotics can inhibit the growth of pathogenic microorganisms.

These acids also take advantage of the pH of the intestinal lumen, which is important for the metabolism of numerous bacteria, enzymes, and carcinogens in the gut (Kerry *et al*., 2018). Probiotics also produce bacteriocins, ethanol, diacetyl, and peptides, all of which help suppress pathogens. Peptides and bacteriocins increase the membrane permeability of target cells, causing a depolarization of the membrane potential which is known to cause cell death (Islam, 2016). In addition, H_2O_2 causes oxidation of sulfhydryl groups, which leads to degeneration of several enzymes, namely peroxidation of membrane lipids, increased membrane permeability of pathogenic microorganisms, and thus cell death (Figueroa-González *et al*., 2016).

Probiotics not only produce antipathogenic bioactive compounds that directly affect pathogens, but also stimulate antipathogenic host defense pathways such as cells of the small intestine and intestinal epithelial cells. Probiotics confer antipathogenic activity by competing for pathogen binding or receptor sites and nutrients available for pathogen's growth (Kerry *et al*., 2018).

Management of Urogenital Infections

According to the Centers for Disease Control and Prevention (CDCP), more than one billion women worldwide suffer from non-sexually transmitted urogenital infections such as *Urinary Tract* Infection (UTI), Bacterial Vaginosis (BV), and some other yeast infections. Urogenital infections also include Sexually transmitted diseases (STDs) such as gonorrhea, candida, and chlamydia which are major causes of morbidity worldwide (Chan, 2016). Among other things, these pathogenic microbes have evolved to drug resistance, requiring the use of non-pathogenic microbes to eliminate these pathogens (Chan, 2016). Microbial vaginal flora is known to influence an increased incidence of urinary tract infections (UTIs).

Intravaginal lactic acid bacteria such as *Lactobacillus delbrueckii subsp bulgaricus, Lactobacillus casei, Lactobacillus brevis, Lactobacillus vaginalis, Lactobacillus salivarius, Lactobacillus reuteri*, and *Lactobacillus rhamnosus* may have the ability to modulate the vaginal microenvironment. An imbalance in the vaginal microbial composition affects the health of the vaginal microenvironment through bacterial vaginosis (BV) and her UTIs. However, using *Lactobacilli* together with probiotics balances the vaginal microbiota and reduces the risk of infection (Daliri, 2015).

Management of Diabetes

The treatment of diabetes involves a multi-disciplinary approach, as no single cure exists (Iqbal *et al*., 2014). Recent studies utilizing techniques such as 16 S rRNA gene sequencing, real-time PCR, and fluorescent insitu hybridization suggest a link between the composition of intestinal microbiota and metabolic disorders such as diabetes and obesity. Probiotics have emerged as a significant tool in controlling these conditions (Larse *et al*., 2010). The gut microbiota is dominated by two main bacterial phyla, Gram-negative Bacteroidetes and Gram-positive Firmicutes. Research has demonstrated that obesity is associated with an increase in Bacteroidetes over time, coupled with a decline in Firmicutes.

For individuals with type-2 diabetes, there is a significant reduction in the number of Firmicutes species, which leads to an increase in the Bacteroidetes-Firmicutes ratio that positively correlates with plasma glucose concentration. Therefore, regulating gut hormones such as gastric inhibitory polypeptide and glucagon-like peptide-1 with the use of probiotic and prebiotic interventions can manage type-2 diabetes (Shehata *et al*., 2016).

Management of Obesity

Obesity can be controlled by stimulating the thermogenic and lipolytic responses of the sympathetic nervous system (Karimi *et al*., 2015). Probiotics such as *Lactobacillus gasseri* BNR17 can reduce the adipocyte tissue that is responsible for the secretion of leptin and adiponectin, while other probiotic microbes such as *Lactobacillus acidophilus*, *Bifidobacterium longum Lactobacillus casei* have hypocholesterolemic effects (Karimi *et al*., 2015).

Desirable Properties of Probiotic Strains

Probiotic strains must fulfill specific safety, performance, and technological criteria to be considered effective (Gibson and Fuller, 2000). They should be of human origin and isolated from the gastrointestinal tract of healthy individuals, possess generally regarded as safe status, and not be pathogenic or associated with diseases. They should also have desirable antibiogram profiles (Saarela *et al*., 2000), be acid-tolerant, adhere to the intestinal mucosal surface, and have antagonistic activity against pathogens. Probiotic strains should stimulate an immune response (Kolida *et al*., 2006), be able to survive environmental conditions, and be easily reproducible and metabolically active without producing off flavors or textures.

Conclusion

The use of probiotics has expanded beyond gut health maintenance and supplementation during antibiotic therapy to encompass a wide range of health applications. As more research is conducted on both established and emerging probiotic strains, future trends indicate that these beneficial microorganisms will become more prevalent in dietary supplements and functional foods that aim to support various preventive health maintenance needs. Functional foods containing probiotics, such as yogurt, beverages, baked goods, preserves, pickles, breakfast cereals, nutrition bars, and other convenient products, offer appealing delivery options for these health-promoting ingredients.

Further investigation is needed to determine the specific medicinal role of probiotics as a functional food or supplement, particularly in the management or prevention of certain acute and chronic diseases. To establish the optimal dose and strains required for each disease state, more research is needed, particularly in areas where evidence is lacking, such as the prevention of hypersensitivity diseases and respiratory tract infections, or where evidence is inconsistent, such as in lipid and blood pressure reduction. Therefore, further research is required before probiotics can be recommended as a reliable method of treatment.

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