CME LIVE OPEN ACCESS

Journal of Medical Microbiology

Review Article

Probiotics: Foods and Health Benefits – An Updated Mini Review

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Received: 2024 Mar 19 **Accepted:** 2024 Apr 08 **Published:** 2024 Apr 29

Abstract

Probiotic organisms are commonly present in water, soil, food, human and animal intestine. Probiotics are live microorganisms or friendly microbes, and they provide numerous health-beneficial effects to the host such as inhibition of adherence and colonization of pathogens, enhanced immune system, reduction of toxins, reduction of inflammatory bowel diseases, reduce cholesterol levels, prevention of cancer, synthesis of vitamins, and production of antimicrobial compounds. Consumer awareness is the main reason for the development of probiotic functional food products. In this regard, probiotics incorporated in food products significantly enhanced the quality, taste, and flavour compared to non-probiotic functional foods. Furthermore, probiotic food products protect against unfavourable conditions and increased shelf-life periods. The present review aims to focus on dairy and non-dairy products improving the quality of the functional product as well as probiotic functional foods supportive to improve consumers› health and prevention of diseases.

Keywords: Probiotics, Dairy, Non-Dairy, Health Development, Prevention of Diseases and Functional Foods.

1. Introduction

Probiotics are defined as live cell microorganisms that when administered in adequate amounts confer health benefits to the host, and these beneficial microorganisms play an important role in maintaining gut microbial balance and improving the health of the host [1, 2]. Lactobacilli and Bifidobacteria species provide beneficial effects to the host, maintaining gut microbial balance and suppressing adherence and colonisation of pathogenic bacteria in the gastrointestinal [GI] tract, delaying cholesterol absorption, activating the immune system, production of digestive enzymes and antimicrobial compounds, reducing colon cancer cells, decrease the faecal enzyme response for changing procarcinogens to carcinogens, atherosclerosis, and coronary disease [3-6]. In addition, oral intake of Lactobacillus rhamnosus GR-1, Lactobacillus fermentum RC-14, Lactobacillus paracasei ST11, and Streptococcus salivarius K12 revealed beneficial effects on, skin immune homeostasis, and oral malodour parameters [7-9]. Furthermore, the probiotic extracellular matrix can enhance clinical results by the transformation of the immune response, expressed in topics with chronic and acute diseases e.g., probiotic administration reduces pouchitis relapse and increases the clinical points in ulcerative colitis patients by enhancement of inflammation [10-13]. In addition, some Lactobacillus plantarum strains isolated from fermented sausages revealed improved adhesion to the gut mucosa compared to strains isolated from non-fermented sausages [14].

Probiotic food products in the global market have received great attention due to their potential health impacts, and a study by Sanap et al. Showed that probiotic supplements provided health effects, and prevention of inflammatory bowel disease, diarrhoea, allergies, high blood cholesterol, respiratory tract infections, urinary tract infections, lactose intolerance, constipation, Helicobacter pylori infection, and cancer [15, 16]. The selection of probiotic strains requires to be carefully measured for positive health effects based on scientific confirmation [17]. According to Kabir et al. The universal trade of probiotic substances, additions, and supplementation to foods reached US$ 50.0 billion in 2020 with a composite yearly growth rate of 8.0% from 2015 to 2020 [18].

Functional food products are defined as natural or processed foods showing known and unknown biological active molecules that are clinically proved and documented for health-beneficial effects for the prevention or treatment of chronic infections [19]. The functional food market consists of probiotics, prebiotics, synbiotics, immunostimulants, nutraceuticals, vitamins, minerals, organic acids, fatty acids, carotenoids, and dietary fibers [20]. Probiotics are incorporated into different types of products; milk-based drinks, fermented milk, infant formula, and nutritional supplements and these products enhance the hosts' health in many ways by improving the gut microbiota, immunomodulation, prevention of diseases, antimicrobial effects, and enhancement of hypercholesterolemia and improved central nervous system function [21-28]. The viability and metabolic characteristic features of importance for probiotics are, incorporated into a raw food material, as storage and GI tract conditions can affect their beneficial characteristics, and the standard viable count of probiotics for health benefits, 106–107CFU/ml or CFU/g, is suggested [29].

The health-enhancing fermented milk products started back in 76 B.C. as the Roman historians Plinio [Plinius] suggested their use for GI tract infections [30]. Microbial fermentation to improve food products has been adopted for centuries by various communities [31]. Food quality enhancement is mostly carried out through lactic acid fermentation and sometimes probiotic fermentation increases the shelf-life period, and nutritional value, and enhances sensory activities [32]. Technological development helps improve the commercial production of various probiotic foods and beverages [33]. Byakika et al. Reported that Lactobacillus sp. and Bifidobacterium sp. passage through the small intestine provide some positive effects: improvements of the gut microbial composition, production of antimicrobial compounds, and gut immunity [34]. In addition, the increasing demand for functional foods has involved the inclusion of probiotics into matrices based on milk, cheeses, vegetables, fruits, and meat products [35]. Bacillus amyloliquefaciens RWL-1, and L. fermentum JN248 are successfully manufactured and incorporated to improve food product quality and the consumers' health [36]. The compositions of food substances i.e., lipid content, type of proteins, carbohydrates, and pH can affect the growth and survival of probiotics in food and can enhance the bioavailability of food factors like isoflavones, flavonoids, and phenolic acids and reduce the level of unwanted substances [36-39]. The inclusion of probiotic functional foods is of importance for the development of functional food products in the market, and probiotic products are mostly marketed in dairy products, but there is a growing interest in developing new functional foods like Vegan probiotic food products [40-42]. The well-known probiotic dairy beverages are sour or sweet acidophilus milk and some kinds of cheeses. The major probiotic strains like L. paracasei, L. casei, Lactobacillus johnsonii, L. rhamnosus, L. plantarum, Lactobacillus acidophilus, Bifidobacterium longum, and Bifidobacterium bifidum are used to produce beverages [43]. Cheeses are one of the most important carriers for L. casei as it has comparatively high pH and fat content, a solid consistency, and a high buffering capacity which are of help to protect the probiotics [44].

1.1. Possible Modes of Action

Molska and Reguła stated three mechanisms of probiotic action [45]. 1. Can regulate the host immune system, improve disease resistance, chronic inflammation in the GI tract as well as probiotic action could be significant for the suppression of neoplastic host cells. 2. Can affect pathogenic microbes in the GI tract and 3. Probiotic bioactive components are helpful to inactivate toxins and detoxification of the host and food substances in the gut. The authors also stated that probiotics and microbial components are valuable applications for the prevention or treatment of colorectal cancer. In addition, some recent studies have suggested a controversial hypothesis that probiotics can be used as a weapon in the fight against COVID-19 [46-49]. Furthermore, possible modes of probiotic actions include synthesis of organic acids and enzymes, increased colonization resistance by competitive space and nutrient intake, enhancing barrier function, small molecules with systemic effects, and connection with gut microbiota by cross-feeding and components transformation, antimicrobial production, and biased microbial stability [50]. Probiotic therapy is an alternative tool for the prevention of certain diseases as well as probiotics play an important role in the production of antimicrobial compounds, enhancement of intestinal barrier function, competition for nutrient substrates, and competitive exclusion of pathogens [51-54]. Numerous studies described that probiotics provide some beneficial effects such as anticancer effects, reduction of allergies, prevention, and treatment of diabetes and obesity, vitamin synthesis, antibacterial activities, improvement of inflammatory processes in lowering cholesterol and triglyceride levels, enhanced behaviour linked to psychiatric disorders and reduced oxidative stress [55- 65].

1.2. Food Product Applications

Probiotic foods contain a high quantity of microorganisms, and a daily intake of 108 and 1011CFU/ day is suggested, present in dairy and non-dairy products [66, 67]. As antibiotic therapy generally affects the intestinal microbiota composition, regular consumption of probiotic foods is supportive of improving the balance of beneficial microbiota composition in the intestine [68, 69]. The global probiotic food product market is rapidly growing due to consumer

awareness, and its impact on food and host health. Today probiotic product in the functional food market ranges from 60% - to 70% [70]. Probiotic foods and drinks in the global market in 2011 were approximately 24.8 billion euros, 31.1 billion euros in 2015, and in 2020 approximately 43 billion euros [71]. Functional foods are defined as foods containing health-enhancing factors beyond traditional nutrients and are also known as medicinal foods, therapeutic foods, designer foods, nutraceuticals, and superfoods [72]. Probiotic cultures are incorporated into different food products like milk, milk powder, milk-based drinks, butter, cheese, ice cream, mayonnaise, vegetables, fruits, meat, cereals, and powder products [73]. Probiotics incorporated into vegetable products, called vegan probiotics can have hypercholesterolemia and anticarcinogenic effects in vitro, and Lactiplantibacillus plantarum-1 and Lacticaseibacillus rhamnosus GG incorporated into the blueberry bagasse provided effects on cholesterol reduction [74].

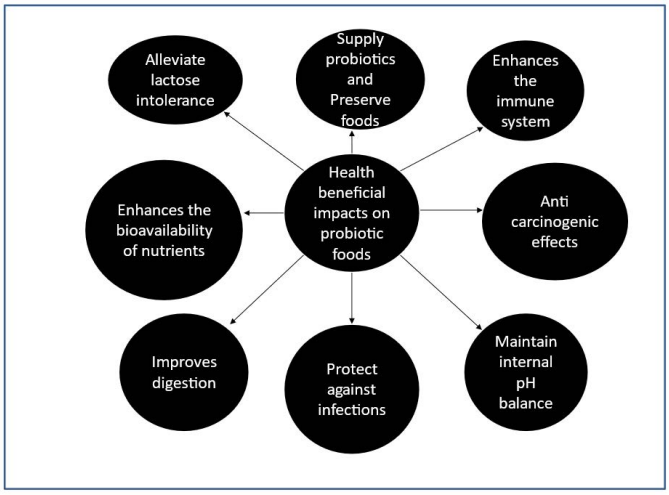

Figure 1: Health Beneficial Impacts on Probiotic Foods.

1.3. Dairy Products

In an early study, Adams et al. Stated the importance of probiotics application in dairy-based foods and beverages [75]. In a recent study, Shori suggested that dairy products are the most suitable carrier for delivering probiotics in the GI tract, and dairy food matrices are used to deliver probiotics in cheese, yogurt, ice cream, and other dairy products [76, 77]. Reported that goat milk fermented by lactic acid bacteria and significantly modulated the allochthonous microbiota in the small intestine, intestinal health, and cell-mediated immunity in mice [78]. However, as the autochthonous was not investigated, one cannot fully conclude the dietary effect on small intestinal microbiota. Dairy product components are an important factor to take into consideration to maintain the viability of probiotics in the food or the use of microencapsulation techniques to increase the viability of probiotics in the GI tract [79]. Production of lactic acid by probiotic bacteria in the dairy fermentation process plays a significant role in food preservation, and preventing spoilage caused by Campylobacter, Clostridium botulinum, Escherichia coli O157:H7, Listeria monocytogenes, Norovirus, Salmonella, Staphylococcus aureus and Shigella [80].

1.4. Probiotic Yogurt

Yogurt is commonly used due to its taste and health benefits and is in some cases the main meal or snack during the day [81]. The term yogurt originates from the Turkish word "yogurt", which means to thicken, coagulate, or curdle [82]. Yogurt and fermented milk give an excellent source of fatty acids like conjugated linoleic acid [CLA], and today CLA is attracting a lot of interest due to immunomodulatory, anti-diabetogenic, apoptotic, anti-obesity, anti-carcinogenic, anti-atherogenic, and osteosynthetic properties [83]. The production of yogurt requires milk to acidify, and the acidification process mainly depends on bacteria such as L. acidophilus, L. casei, Lactobacillus delbrueckii, L. paracasei, Streptococcus thermophilus, and B. lactis [84]. Yogurt provides positive impacts on human health like reducing cholesterol levels in blood serum and lowering blood pressure and heart rate, including antihypertensive effects [85, 86]. Single or combined administration of probiotics in yogurt significantly increased calcium, phosphorus, and protein ash levels [87]. L. acidophilus La5 and B. lactis Bb12 incorporated to yogurt provided beneficial effects by enhancing fasting blood glucose and decreasing HbA1c and activating enzymes from the detoxifying system in patients with T2DM [88]. Yogurt-added Lactobacillus sp. has high nutritional value as well as strong antimicrobial effects against E. coli and Gardnerella vaginalis [89] and has shown potential effects to decrease diarrhoea in irritable bowel syndrome patients [90]. In a French randomized study on humans examined the effect of additives and non-additive yogurt on diarrheal patients and displayed that yogurt additives provided better results on the diarrheal patients compared to the control group not receiving yogurt. In addition, yogurt inhibited or suppressed Salmonella enteritidis ATCC 13076, L. monocytogenes ATCC 7644, E. coli O157: H7 ATCC 35150, Cronobacter sakazakii ATCC 29544, and Campylobacter jejuni ATCC 3329 in the GI tract [91].

1.5. Probiotic Milk

Several probiotic bacteria are reported in fermented milk; B. longum, Enterococcus faecium, L. plantarum, Leuconostoc cremoris, Lactobacillus helveticus, Lentilactobacillus hilgardii, Lactobacillus alimentarius, Lactobacillus bifermentans, L. paracasei, Lactobacillus kefiri, Lactobacillus kefiranofaciens, Lactobacillus pentosus, Lactococcus lactis, and Leuconostoc pseudomesenteroides [92-94]. Fermented milk provides a positive response on plasma cholesterol levels, decreases low-density lipoprotein levels in hypercholesterolemic persons, reduces blood pressure, and prevents hypertension [95]. The consumption of kefir notably reduces total cholesterol, triglycerides, and LDL cholesterol, reduction in blood glucose level and HbA1C, and enhances insulin resistance [96, 97]. Kefir administration to 48 patients [1.6 ml/kg for men or 1.9 ml/kg for women] for 12 weeks showed significantly enhanced insulin resistance, and reduced homocysteine levels, compared to the control groups [98]. Fermented milk provides some health-beneficial effects, reduced serum cholesterol level, enhancement of the GI tract, prevention of cancer, enhanced immune response, and development of cognitive impairments [99-101]. Milk fermented with L. plantarum and L. fermentum provided positive impacts on experimental colitis, and administration of the fermented

milk reduced the total number of monocytes, neutrophils, leukocytes, and inflammatory factors repair tissue morphology and notably increased IL-10 and IgA in mice vs. the control group [102]. Consumption of kefir over eight weeks notably decreased bloating scores through the modulating of the gut microbial community in IBD patients [103]. An interesting finding, regarding fermented milk, is that administration reduces blood pressure and cholesterol levels in randomized double-blind human trials compared to the control group, and kefir administration to mice significantly reduce the risks of antitumor and antimutagenic effects [96, 104, 105].

1.6. Probiotic Cheese

It is generally accepted that cheese is a good delivery carrier for probiotic dairy products compared to non-dairy products [106]. Fermented dairy products improve the survival of probiotic bacteria during manufacture progress but probiotic supplementations did not cause any sensory divergence of the cheese [107-109]. Probiotic-incorporated cheese products increase the nutritional value and consumer awareness of foods and health, and probiotic cheese products improve sensory properties and health claims like reducing oxidative stress in the liver, lungs, and intestine [110-112]. Probiotic Mozzarella cheese prior to preparation of semi-hard cheese revealed a decrease in the number of Lactobacillus sp., from 108 to 107CFU/g after 180 days of ripening [113]. Furthermore, probiotic-supplemented cheeses have good sensory properties compared to non-probiotic-added cheese, and the probiotic supplement in cheeses not only enhances the shelf-life period but also increases the organoleptic properties of the cheese [114, 115]. Probiotic survival at different stages of cheese ripening was examined and the requirement of the probiotic level was not less than 108 [CFU/ml] to provide health beneficiary impacts on the host [116].

1.7. Probiotic Butter

Supplementations of probiotic strains have also been incorporated in butter play by modulating the health of the human, because a balanced intestinal microbiota, reduces the risk of development of various diseases such as cancer, colitis, lactose intolerance, heart diseases, and obesity [117]. However, the high quantity of saturated fatty acids present in butter is supportive of the action of cardiovascular diseases and diabetes in patients [118]. Probiotic LAB incorporated in butter, butter significantly reduced serum cholesterol levels by in vitro and in vivo methods [119].

1.8. Probiotic Ice Cream

Ice cream supplemented with probiotics provided positive effects, improved human health, and enhanced the nutritional value of the ice cream product, and probiotics viability level is better in ice cream products compared to other functional dairy and non-dairy products based on avocado [120, 121]. However, some factors can affect the viability of probiotics in ice cream during the progress stage like the fermentation process [in the case of fermented ice cream], freezing and churning processes, overrun process, frozen storage period, and melting/thawing of the product [67]. Lactiplantibacillus plantarum 299v incorporation in ice cream frequently conveys better quality and characteristic features than non-probiotic ice cream [122]. According to El-Sohaimy and Hussain, ice cream is a suitable probiotic delivery carrier for the survival of the bacteria in the human GI tract, but the major problem is that freezing after two weeks lowered the log CFU value of the probiotics [67, 121].

1.9. Non-Dairy Products

Cereal Food Products

Cereals such as wheat, maize, oat barley, and other grains are rich fibre sources, and they revealed beneficial effects, these products are used to improve the survival and viability of probiotics in the GI tract [123-127]. Cereal fermentation by probiotics can decrease nondigestible carbohydrates, increase the level of lysine, and availability of vitamin B group, degradation of phytates, and release minerals [manganese, iron, zinc, and calcium] [128]. Cereals, bread, biscuits, and beverages fermented with LAB revealed pH reduction in the intestine, improvement of antimicrobials, enzymes, and vitamins, reduction of serum cholesterol, regulation of the immune system, revival and restore the gut microbiota after diarrhoea, reduce food allergens, antioxidative activity and reduce lactose malabsorption symptoms [129]. L. acidophilus, Lactobacillus bulgaricus, B. bifidum, and S. thermophilus, are used to develop rice-based food product applications [130]. The Turkish fermented beverage “boza” is produced from cereal/millet flour with water and fermented by Lactobacillus sp., and Saccharomyces cerevisiae, the product contains different molecules, proteins, enzymes, carbohydrates, vitamins, and antioxidants and shows antioxidant with some benefits to human health like decrease obesity in addition to the advantages that they do not have undesirable compounds such as cholesterol and lactose [131]. In addition, supplementation of LAB and bifidobacteria in the fermentation of soy milk significantly increased antioxidant activities and serum lead levels but in rats no significant effect on blood parameters such as red blood cell counts, haematocrit and haemoglobin levels, and superoxide dismutase [SOD] activity and malondialdehyde [MDA] were revealed [132]. Oats contain high levels of β-glucans [organic acids and amino acids] helpful to enhance the growth of Lactobacillus reuteri, L. acidophilus, and B. bifidum [133]. Extraction of β-glucan from oat bran and β-glucan samples derived with xylanase and administrated with B. bifidum revealed a positive impact on B. bifidum in the human colon [134]. In grape flavour beverages, the effect of various concentrations of oat bran extract in a 14-day study considerably increased the viability of probiotics [log 8–9 CFU/g] [135]. Based on an elevated level of phenolic substances and nutritional properties of oat bran extract significantly decreased the viability of B. lactis after 21 days of storage [136].

1.10. Fruit Food Products

Different probiotics are used as supplements to fruits and vegetables like pineapple, cranberry, strawberry, sweet lime, mango, grapes, cashew apple, olive, carrot, beetroot, and oranges [137]. According to Bustos et al, fruits and vegetables are suitable carriers for the delivery of probiotics, but the viability and stability of the probiotics in these foods are highly strain dependent [138]. Durian fruit, a product

called "tempoyak" manufactured in Malaysia is fermented with Levilactobacillus brevis, Leuconostoc mesenteroides, and L. fermentum [139]. Different types of fruits, and vegetables are used to make turşu products, and the LAB turşu can be of help against cirrhosis and diarrhoea [140]. B. longum and L. plantarum is the suitable carrier delivery for noni juice as well as these products considerably increased antioxidant level, reduce cholesterol level and enhance product quality [141]. Cornelian cherry juice fermented with L. plantarum ATCC 14917 evaluated the viability in the juice during cold storage, but no sensory variations were noted between the fermented and non-fermented samples [142]. Star fruit used as a carrier substance for probiotic delivery improved the growth and viability of L. helveticus L10, L. paracasei L26, and L. rhamnosus HN001, and the final cell counts were around 108CFU/ml [143]. de Oliveira et al. Reported the viability of probiotic Pediococcus acidilactici CE51 in concentrated orange juice at pH 4.5 and pH 6.5 and stored at 4 ◦ C and 35 ◦ C for 35 days, and at the end of storage a viable count of P. acidilactici CE51between log 7.2 and 8.5 CFU/ml was noticed, and based on their results the authors suggested that orange juice is a suitable carrier for probiotic delivery [144]. In another study, was P. acidilactici CE51 successfully incorporated into two sour cherry cultivars after pH 4.5- 6.5 adjustment [log 9 CFU/ml] [145]. Mantzourani et al. Reported that pomegranate juice fermented with L. plantarum ATCC 14917 in a 28-day storage study, and after four weeks of storage an increased viability of the probiotic was reported, but further storage, 28 days, decreased the viability of log L. plantarum, to 8.83CFU/ml [146]. Nguyen et al. Reported that pineapple fermented with L. acidophilus La5, L. plantarum 299V, and B. lactis Bb12 probiotics process significantly improved the growth and viability of the probiotics in pineapple [147]. Bergamot juice supplemented with probiotics at 72h fermentation, short storage, increased the viability of L. plantarum to log 8.52 CFU/ml, and the juice fermented with a probiotic enhanced antioxidant activity and antibacterial properties [148]. Genevois et al. Reported that pumpkin waste included with L. casei during 35 days of storage at 8 ◦ C and 22 ◦ C, but after short-term storage [21 days] at 22 ◦ C an increase of bacterial viability count to 7.3 log CFU/g of was noticed while further storage for 35 days the bacterial viability counts decreased to 6.61 logs CFU/g [149].

1.11. Vegetable Food Products

Vegetables contain carbohydrates, vitamins, minerals, and phytochemicals, and fermented vegetables are the new way to improve plant-based products like beet, carrot, radish, artichoke, cabbage, broccoli, celery, aloe vera, soy, almond, and walnut [150, 151]. Barbu et al. Reported that beetroot cips or lyophilized products are a suitable carrier for L. plantarum, and after 21 days of storage, the probiotic level increased in the products. In a study evaluating vegetable juices, tomato, carrot, and beetroot, Goderska et al. That these juices are of help for lactose intolerant people who cannot intake probiotics via milk and milk products and people on a fat-free diet as the juices contain zero fat and high fibre content [152, 153].

1.12. Meat Products

The most frequently used probiotics in fermented meat products are L. plantarum, L. sakei, L. paracasei, L. casei, and L. rhamnosus [154-156]. The inclusion of probiotics in meat products considerably increased taste, flavour, quality, and moisture conditions [157]. However, successful incorporation is dependent on viability during processing and product shelf life as some technological advancements can affect the survival of the probiotics in fermented meat products like pH, acidity, water activity, processing and storage temperature, presence of other microorganisms, the concentration of additives [salt, sugar, nitrite, and nitrate], and composition of the protein matrix [158]. In a study evaluated strategies to improve meat products' quality, Ursachi et al. Reported that. L. casei showed a strong capacity to suppress the growth of Pseudomonas, enterobacteria, and staphylococci [159]. L. plantarum TN8 [108CFU/g] incorporated into meat revealed an increased shelf-life period of the product as well as notably improved oxidation stability of lipids, proteins, texture profile, and colour parameter of the product during refrigerated storage condition,10 days at 4°C.

2. Conclusion

Natural mediated functional foods awareness is the major development for probiotic functional foods as probiotic functional foods provide numerous health-beneficial effects, and dairy and non-dairy products are suitable carriers for the delivery and growth of probiotics. Previously, dairy products were the most common functional food, but nowadays non-dairy functional products are also available. In the future, various kinds of techniques used to encapsulate the probiotics to improve the viability and stability of probiotics, improved functional product quality, and health benefits, merits investigations.

Acknowledgment

This research received no external funding.

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