

The Use of Prebiotics of Plant Origin in Functional Milk Products

Ozge Ozcan¹, Tulay Ozcan^{2,*}, Lutfiye Yilmaz-Ersan², Arzu Akpınar-Bayazit², Berrak Delikanlı²

¹Department of Medical Laboratory Techniques, Vocational College of Health Services, Kırklareli University, Turkey

²Department of Food Engineering, Uludağ University, Turkey

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Abstract A food that contains biologically active compounds/components which beneficially affects one or more target functions such as reduction of chronic diseases in the body along with its nutritional effects is named as “functional product”. Among these foods or beverages that are fortified through addition of exogenous functional compounds (i.e. prebiotics) or using microorganisms that produce biogenic compounds or have probiotic features (probiotics). Probiotics are described as cultures of live microorganisms that are beneficial to health when administered to humans or animals, improve properties of gastrointestinal microflora. Prebiotics cannot be digested by small intestinal enzymes but are fermented by probiotic bacteria the large intestine. Much research attention is focused on the combined use of probiotics and prebiotics, generally known as symbiotic, to get their synergistic health properties. This review provides an insight on the current knowledge about the potential sources of plant-based prebiotics used in dairy industry.

Keywords Prebiotic, Probiotic, Plants

1. Introduction

The food industry is currently focusing on which attribute is more important on consumers' preference. The global trend is the increasing demand for convenience and health-beneficiary foods, of which particularly boost the immune system, reduce the risk of disease, and enhance health. Such foods must fit into lifestyles of the society providing convenience of use, good sensorial attributes, and an acceptable price-value ratio [1]. The interest for such products constitutes current and future main research objectives in food innovations and has led to the development of foods defined as “functional foods”.

Functional foods, can be described as “foods that contain some health-promoting component(s) beyond traditional nutrients” which demonstrate their effects in amounts that

can normally be expected to be consumed in the diet, and are not pills or capsules, but part of the normal food pattern” [2-4]. In general, a food that nonetheless conveys consumers the essential nutrients but also extends its health benefits far beyond basic nutrition can be defined as functional food [5-7].

Milk is a complex mixture of components like biologically active substances i.e. immunoglobulin, enzymes, antimicrobial peptides, oligosaccharides, fatty acids, saccharides, hormones, cytokines and growth factors which designates it as “physiologically functional” food [8]. The dairy industry has responded to consumers' awareness and perception in functional foods by enhancing the existing health attributes of milk and milk products [9,10].

Development of functional milk products, i.e. yogurt, cheese and fermented drinks, containing probiotics and prebiotics could be an alternative to enhance health promoting microbial flora in the intestine, which depend on age, diet, stress, disease and drugs taken [11-13].

2. Probiotics

The word “probiotic” was initially used as an antonym of the word “antibiotic.” It is derived from Greek words pro- and biotos and translated as “for life” [14-17]. Food and Agriculture Organization (FAO) and World Health Organization (WHO) defined probiotics as “live microorganisms which when administered in adequate amounts confer a health benefit on the host” [18]. In other words, probiotics are the microorganisms (bacteria or yeasts) that can help to reestablish and recolonize the human intestinal microbiota to enhance beneficial health effects on the host [19].

Probiotic products with health claims should have viable microorganisms at levels of 10^6 – 10^7 cfu mL⁻¹ or cfu g⁻¹ or even at higher levels at the time of consumption [20-23]. Some selected strains used in dairy food products as probiotics are *Lactobacillus*, *Bifidobacterium*, *Lactococcus*, *Streptococcus*, and *Saccharomyces* (Table 1) [24-32].

Table 1. Cultures used as probiotic

Lactic acid bacteria	<i>L. cellobiosus</i> , <i>L. delbrueckii</i> , <i>L. brevis</i> , <i>L. acidophilus</i> , <i>L. reuteri</i> , <i>L. curvatus</i> , <i>L. fermentum</i> , <i>L. plantarum</i> , <i>L. johnsonii</i> , <i>L. rhamnosus</i> , <i>L. helveticus</i> , <i>L. salivarius</i> , <i>L. gasseri</i>
<i>Bifidobacterium</i> species	<i>B. adolescentis</i> , <i>B. bifidum</i> , <i>B. breve</i> , <i>B. infantis</i> , <i>B. longum</i> , <i>B. thermophilum</i>
<i>Bacillus</i> species	<i>B. subtilis</i> , <i>B. pumilus</i> , <i>B. lentus</i> , <i>B. licheniformis</i> , <i>B. coagulans</i>
<i>Pediococcus</i> species	<i>P. cerevisiae</i> , <i>P. acidilactici</i> <i>P. pentosaceus</i>
<i>Streptococcus</i> species	<i>S. salivarius</i> ssp. <i>thermophilus</i> , <i>S. intermedius</i>
<i>Bacteriodes</i> species	<i>B. capillus</i> , <i>B. suis</i> , <i>B. ruminicola</i> , <i>B. amylophilus</i>
<i>Propionibacterium</i> species	<i>P. shermanii</i> , <i>P. freudenreichii</i>
<i>Leuconostoc</i> species	<i>L. mesenteroides</i> ssp. <i>mesenteroides</i>

Probiotics which possess antimicrobial, antidiarrheal, and antiinflammatory properties offer many clinical applications (Figure 1) [33].

The criterion to select and maintain the efficacy of a microorganism as probiotic are i) to have high technological properties which allow them to be manufactured and

incorporated into food products keeping their viability and functionality with pleasant flavors, tastes or textures; ii) to be resistant to low pH, gastric juice, bile juice, pancreatic juice, iii) to be able to survive through the upper gastrointestinal (GI) tract, and arrive alive and colonize at its site of action; iv) to be comparable to human gut microbiota; iv) to accumulate the microbial metabolites to prevent, manage and treat disorders and chronic diseases; and vi) to be able to function in the gut environment with adherence to intestinal cells surfaces and mucus glycoproteins via stimulation/suppression of beneficial bacteria and suppression of harmful bacteria [34-36].

Probiotic strains (especially *Lactobacillus* and *Lactococcus* species) inhibit the growth of pathogenic microorganisms [37], by occupying the mucosal layer and epithelial cell surface [38], and also by producing antimicrobial agents such as bacteriocins or bacteriocin-like molecules, organic acids, and hydrogen that could suppress the growth of harmful microorganisms [39].

The major limitation of probiotics is they must have high viability in the product and remain alive in the gut to exert their beneficial effects. To overcome this drawback the concepts of “prebiotics” or “colonic foods” have been developed.

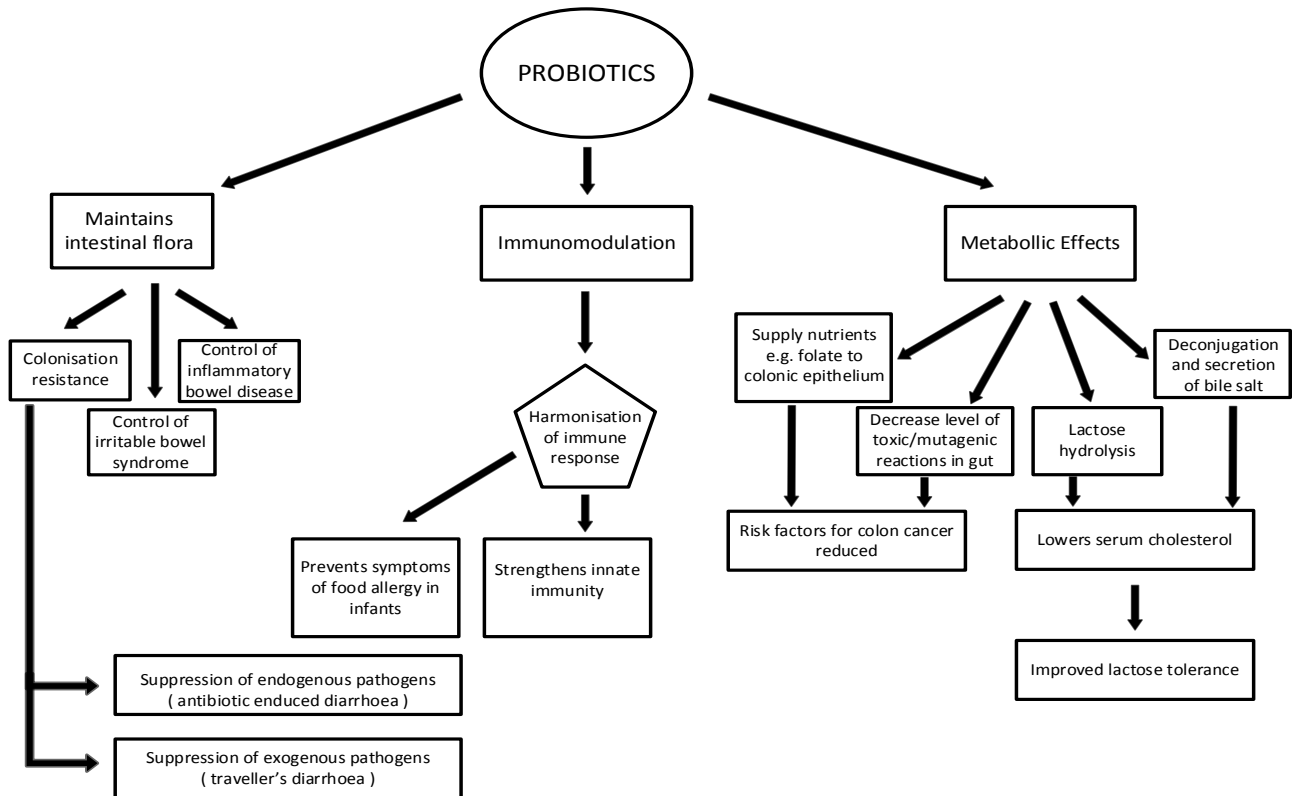


Figure 1. Potential and established effects of probiotic bacteria

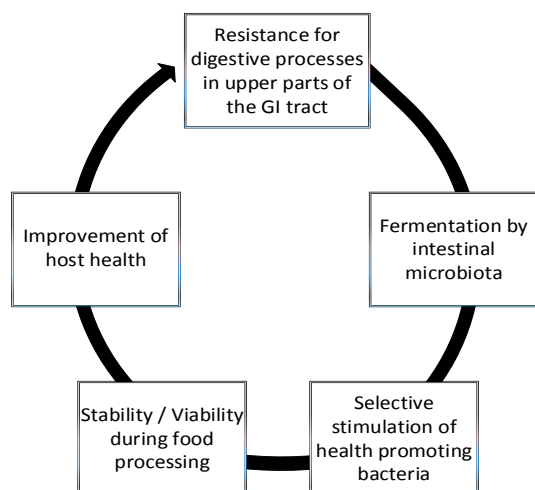


Figure 2. Criteria for a substance to be classified as a prebiotic

The concept of prebiotics was first introduced in 1995 [40], and they have gained attention in industry and academia due to their potential health benefits. Prebiotics are “non-digestible food ingredients that beneficially affect the host by selectively encouraging the growth and/or activity of one or a limited number of favorable bacteria in the colon” [41-44]. For a prebiotic the selection criteria is the substrate must not be hydrolyzed/absorbed in the stomach or small intestine, however, must be selectively used by microorganisms in the large intestine (Figure 2) [45-48].

The probiotics perform more efficiently in the presence of prebiotics, and the beneficial potential of live microorganisms could be enhanced by additional benefits of the prebiotic. The increased amount of prebiotics in the diet, the increased healthy bacterial gut flora of the host [49]. Prebiotics have the ability to improve the growth and metabolic activities of probiotics [50,51].

3. Prebiotics

The function of a prebiotic component is selective stimulation of certain intestinal bacteria, particularly lactic acid producing microorganisms such as *Bifidobacteria* and *Lactobacilli*, resident in the gut rather than introducing an exogenous species. Prebiotics cannot be digested by enzymes in the small intestine but are fermented by probiotic bacteria in the large intestine. Short-chain fatty acids (SCFA), mainly acetate, propionate, and butyrate are formed via

fermentation and due to the decrease of pH possible reduction in the numbers of pathogenic microorganisms can occur (Figure 3) [52-54]. The fermentation of prebiotics by the probiotic bacteria improves the host’s health by enhancing the absorption of minerals such as Ca, Mg, and Fe and producing compounds capable of preventing colon cancer [40].

The prebiotic compounds can be classified based on their chemical nature, chain length or degree of polymerization (DP), mode of usage, etc. Depending on the chemical nature, prebiotic compounds are categorized into three types: saccharide derivatives (disaccharides, oligosaccharides and polysaccharides), proteins or peptides, and lipids [55].

Most of the prebiotics used as food adjuncts are saccharide derivatives and mainly from plants. This family of compounds includes several oligosaccharides (namely fructo-, gluco-, galacto-, isomalto-, xylo-, and soy-oligosaccharides), inulin, lactulose, lactosucrose, guar gum, resistant starch, pectin and chitosan. Potential plant sources for prebiotic carbohydrates are cereals and legume crops like barley, wheat, chickpea and lentils; vegetables like chicory, Jerusalem artichoke, onion, garlic, okra, and leek; and fruits like dragon fruit, jack fruit, palm fruit, nectarine and mushroom [56-64].

Foods may naturally contain prebiotics or can be fortified with prebiotics during manufacturing, in order to improve the functional efficacy of probiotics. When both prebiotics and probiotics are present in a food, then, those foods are referred to as “synbiotic” [10, 65]. The “synbiotic” product, which refers to the “combination of prebiotics and probiotics”, act as a nutritional supplement with the ultimate goal of conferring the advantageous health benefits to the host [66-69]. Synbiotics are particularly preferred since probiotics can tolerate oxygen, low pH, and unfavorable temperature and survive in the digestive system when prebiotics are present [70-72].

Nowadays, prebiotics are included in many food formulations, especially in dairy products, in order to promote the growth of probiotics along with to improve the nutritional quality (Table 2). Therefore, incorporation of prebiotics into milk products, in particular those containing probiotic bacteria, would potentially lead to a product with improved mucosal surfaces of host and production of antimicrobial compounds to inhibit the pathogens, aside with fermentation and biopreservation of the food [73-75].

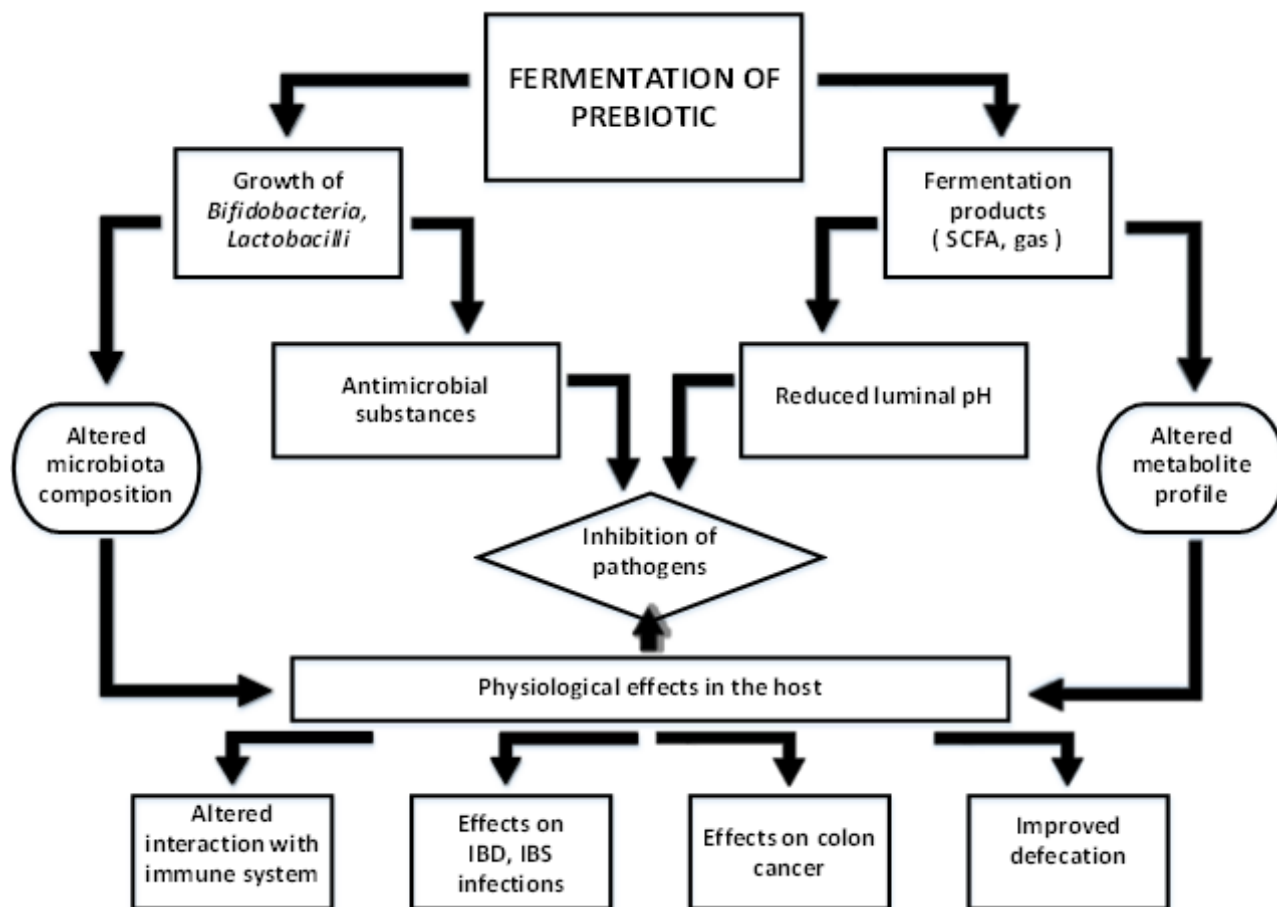


Figure 3. Potential and established effects of prebiotic (IBD: Inflammatory bowel disease, IBS: Irritable bowel syndrome)

Table 2. Some dairy product applications of prebiotic ingredients

PREBIOTIC INGREDIENT	APPLICATION	FUNCTIONALITY	REFERENCE
Lupin Seed	Fermented Milk	<ul style="list-style-type: none"> Reduction of fermentation time Increase probiotic bacteria count 	[76]
Triticale bran	Yogurt	<ul style="list-style-type: none"> A new prebiotic and antioxidant source 	[77]
Lupin	Fermented Milk	<ul style="list-style-type: none"> Increase growth and metabolic activity of <i>Bifidobacteria</i> 	[78]
Oat bran, Green Banana Flour	Dairy Fruit Beverage	<ul style="list-style-type: none"> Increase the survival of <i>Lactobacillus casei</i> (LC-1) 	[79]
Lemon and Orange Fibers	Fermented Milk	<ul style="list-style-type: none"> Enhance bacterial growth and survival of probiotic bacteria Increase sensorial properties 	[80]
Lentil Flour	Yogurt	<ul style="list-style-type: none"> Improve the physical and rheological properties of yogurt 	[81]
Pulse ingredients (pea protein, chickpea flour, lentil flour, pea fibre, soy protein concentrate and soy flour)	Yogurt	<ul style="list-style-type: none"> Increase growth and metabolic activity of probiotic and yogurt starter cultures 	[82]
Apple, Banana and Passion Fibers	Yogurt	<ul style="list-style-type: none"> Improve the fatty acid profile of yogurts Develop new high value-added fermented dairy products 	[83]
Tomato Pulp	Dairy-Based Tomato Spread	<ul style="list-style-type: none"> Enhance bacterial growth and survival of probiotic bacteria Increase sensorial properties Develop functional foods. 	[84]
Quinoa Flour	Fermented Milk	<ul style="list-style-type: none"> Increase nutritive value Increase the appeal of the product to consumers 	[85]
Apple, Banana and Grape Flour	Fermented Milk	<ul style="list-style-type: none"> Develop alternative for functional fermented milk production Increase the viability of probiotic strains 	[86]
A Grain Mixture (wheat, rye, oat, barley and millet)	Yogurt	<ul style="list-style-type: none"> Reduction of energy in foods as sugar replacement Increase the acceptance of fiber-enriched yogurt 	[87]

4. Conclusions

Changes in lifestyle and eating habits have led to considerable multiplication of health problems and chronic diseases. Due to growing global concern on nutrition and personal health, functional foods are gaining public acceptance in many countries. Fermented foods are of great significance since they provide and preserve nutritious foods in a wide diversity of flavors, aromas and textures, while enriching the human diet. In this context, the consumer perception and demand for fermented dairy products with "health promoting" properties, such as synbiotic and probiotic products, have increased. This is a key factor driving value sales growth in global markets.

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