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Probiotics as functional food: microbiological and medical aspects

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Abstract

Probiotic bacteria are sold mainly in fermented foods, and dairy products play a predominant role as carriers of probiotics. Functional dairy foods are well suited to promoting the positive health image of probiotics for several reasons: (i) fermented foods and dairy products in particular, already have a positive health image by their traditional use for centuries; (ii) people are familiar with the fact that fermented food contain living microorganisms; (iii) probiotics are used as starter to join together the positive images of fermentation and probiotic cultures. Probiotics are defined as live bacterial preparations (food or medicine) with clinically documented health effects in humans. Most probiotics exert beneficial effects by modulating the mucosal barrier function and immune activity. Probiotics have specific properties and targets in the human intestinal tract and intestinal microbiota. Understanding the mechanisms by which probiotics influence the normal intestinal microflora and counteract aberrancies in microflora can facilitate the use of probiotics for dietary management and reduction in risk of specific diseases. In reference of the immune system, many studies have pointed out that not only pro- and prebiotics, but also single micronutrients incorporated into functional foods contribute to an enhancement of immunocompetence. In this article, the effect of some functional foods and ingredients such as probiotics and selenium on health and especially immune function are reviewed.

Key words: functional dairy products, functional foods, probiotics, selenium.

Introduction

The term "functional food" was first introduced in Japan in the mid-1980s and refers to processed foods containing ingredients that aid specific bodily functions in addition to being nutritious (Swinbanks, O'Brien 1993). Generally, they are considered as those foods intended to be constituted as part of a normal diet, and that contain biologically active components, which offer the potential of enhanced health or reduced risk of disease.

Research has demonstrated that nutrition plays a crucial role in the prevention of chronic diseases, as most of them can be related to diet. Functional food enters the concept of considering food not only necessary for living but also as a source of mental and physical well-being, contributing to the prevention and reducing of risk factors for several diseases or enhancing certain physiological functions. Dairy products form the major part of functional products. To understand their success it is important to realise that milk is a natural and highly nutritive part of a balanced daily diet. Developing functionality in dairy-based products simply means modifying and/or enriching the healthy natural characteristics of the original base. Milk and some other dairy products were recognised as important foods as early as 4000 B.C. The Roman historian Plinio recommended the use of fermented milk for treating gastrointestinal infections. The French paediatrician Tissier proposed in the early 1900s that bifidobacteria could be effective in preventing infections in infants, as they were the predominant component of the intestinal microflora in breast-fed infants. Then Metchnikoff suggested that consumption of fermented milk could reverse the putrefactive effects of the gut microflora. This concept has developed particularly over the past two decades through trend scientific evidence based on placebo-controlled clinical trials showing that particular strains have associated health benefits.

Nowadays dairy products are excellent media to generate an array of products that fit to current consumer demand for functional food. Fermented dairy products enriched with probiotic bacteria have developed into one of the most successful parts of functional foods. The food industry is especially active in studying probiotics because the gastrointestinal tract is one of the richest zones of biodiversity within the body with at least 450 known species of microorganisms commonly found there. Some of the most

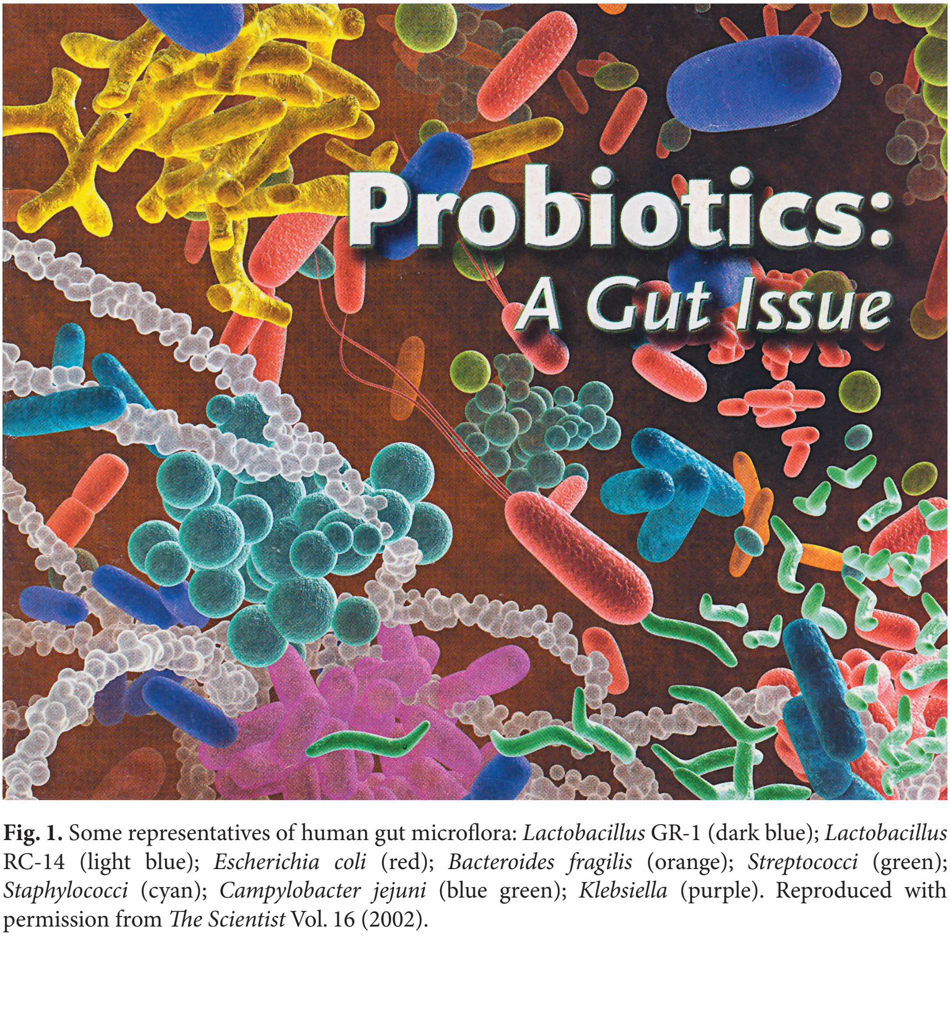

Fig. 1. Some representatives of human gut microflora: *Lactobacillus* GR-1 (dark blue); *Lactobacillus* RC-14 (light blue); *Escherichia coli* (red); *Bacteroides fragilis* (orange); *Streptococci* (green); *Staphylococci* (cyan); *Campylobacter jejuni* (blue green); *Klebsiella* (purple). Reproduced with permission from *The Scientist* Vol. 16 (2002).

Table 1. Microorganisms considered as probiotics (Holzapfel et al. 2001).

Lactobacillus	***Bifidobacterium***	**Other lactic acid bacteria**	**Non-lactic acid bacteria**
L. acidophilus	*B. adolescentis*	*Enterococcus faecalis*	*Bacillus cereus* var. *toyoi*
L. amylovorus	*B. animalis*	*Enterococcus faecium*	*Escherichia coli* Nissle 1917
L. casei	*B. bifidum*	*Lactococcus lactis*	*Propionibacterium freudenreichii*
L. crispatus	*B. breve*	*Leuconostoc mesenteroides*	*Saccharomyces cerevisiae*
L. delbrueckii subsp. *bulgaricus*	*B. infantis*	*Pediococcus acidolactici*	*Saccharomyces boulardii*
L. gallinarum	*B. lactis*	*Streptococcus thermophilus*	
L. gasseri	*B. longum*	*Sporolactobacillus inulinus*	
L. johnsonii			
L. paracasei			
L. plantarum			
L. reuteri			
L. rhamnosus			

important representatives are shown in Fig. 1. Functional dairy products have been the focus of intensive research and product developments over the last two decades regarding putrefactive intestinal bacteria; there has been much interest in the possible health benefits of probiotic microorganisms. Dairy products, accounting for 65 % of the total European functional foods market, are at the forefront of probiotic developments (Hilliam 2003).

Probiotics and prebiotics: definition and mechanism of action

Vergin first introduced the term “probiotics”, when he compared in his paper “Anti- and Probiotika”, the detrimental effects of antibiotics and other antimicrobial substances on the gut microbial population with factors “probiotika” favourable to the gut microflora (Vergin 1954). Then probiotics were defined as non-pathogenic microorganisms when ingested, exert a positive influence on host health or physiology (Fuller 1989). Now, the definition of Food and Agriculture Organisation of the United Nations/World Health Organisation (FAO/WHO 2001) for probiotics is “Live microorganisms, which when administered in adequate amounts, confer a health benefit on the host”. This definition retains the historical elements of the use of living organisms for health purposes but does not restrict the application of the term only to oral probiotics with intestinal outcomes (Reid 2006). This is important considering that vaginal applications of probiotics have existed for more than 20 years (Reid, Bruce 2006).

Microorganisms that are probiotics (Table 1) in humans include yeast (Periti, Tonelli 2001), bacilli (Pinchuk et al. 2001), *Escherichia coli* (Midtvedt 1997), enterococci (Lund, Edlund 2001), and the more commonly used bifidobacteria and lactic acid bacteria, such as lactobacilli, lactococci and streptococci (Salminen et al. 1998; Isolauri et al. 2002). The International Dairy Federation has recently published a bulletin summarising the evidence for the effect of probiotic cultures on a range of diseases and disorders in humans. The bulletin No 380/2003 contains a section (Ouwehand et al. 2003) reviewing the evidence for clinical effects in an extensive range of conditions including lactose maldigestion, diarrhoea, immune modulation, inflammatory bowel syndrome, constipation, necrotising enterocolitis, *Helicobacter pylori* infection, small bacteria overgrowth, colorectal cancer, breast cancer, allergy, serum cholesterol and blood pressure decreasing, coronary heart disease, urinary tract infection, upper respiratory tract and related infections. Thereby probiotics have multiple mechanisms of action (Table 2), including prevention of pathogenic bacterial growth, binding to or penetration of pathogens to mucosal surfaces, stimulation of mucosal barrier function, production of antimicrobial agents or altering immunoregulation, decreasing proinflammatory and promoting protective molecules (Sartor 2005; Novak, Katz 2006). It was demonstrated (Meier, Steuerwald 2005) that not only viable or dormant bacteria administered to the intestinal tract but also probiotic DNA is active, even if injected subcutaneously. Attention is now focusing on the intestinal survival of probiotic bacteria, their competition with the abundant resident microbiota, identification of activity and clarification of mechanisms of action. Probiotics have to survive gastrointestinal transit and arrive viable to contribute positively to the activity of the intestinal microflora, and thus, the health of the host (Table 3). A recent paper hypothesised that probiotics might even help detoxification in cases of mercury poisoning (Brudnak 2002).

Another interesting aspects concerns the antigenotoxic activities of probiotics. Our experiments have suggested that the potential genotoxic effect of furazolidone, nalidixic acid and 4-nitroquinolone-N-oxide could be strongly reduced by *in vitro* co-incubation with probiotic bacteria, belonging to three genera and probiotic yeast (Raipulis et al. 2005; Toma et al. 2005). Surprisingly, the nonprobiotic yeast *Saccharomyces carlsbergensis* also possesses antigenotoxic activity but to a minor extent (Toma et al. 2005). The antigenotoxic properties were shown only by live cells but heat treated cells did not act as an antigenotoxin. These results are of considerable interest with the increasing demand

Table 2. Some examples of target specific search for optimal probiotics (Salminen et al. 2005)

Target for probiotic action	Selection criteria
Alleviation of lactose maldigestion probiotics	High lactase producing strongly site specific symptoms
Intestinal inflammation	Site specific adhesion properties, anti-inflammatory cytokine expression, mucosal properties to alleviate permeability disorder and gut microflora abberancy
Alleviation or food allergy symptoms, reducing the risk proteolytic properties of atopic disease	Adherence to small intestine, induction of local transforming growth factor-β production
Reducing the risk of colon cancer	Target specific adhesion to distal or proximal colon, mucosal butyric acid production, competitive exclusion of inflammatory bacteria, toxin binding and promotion of nontoxigenic mucosal microflora

Table 3. The probiotic effects reported and their putative mechanisms (Sanders 2003)

Benefit	Function	Proposed mechanism
Digestive comfort	Irritable bowel syndrome, symptoms affecting the gastrointestinal tract in general (constipation, non-pathogenic diarrhea, distension, flatulence, cramp, halitosis of a digestive cause)	Change in populations or activities of the intestinal microflora
	Lactose intolerance	Delivery of microbial lactase to the small intestine
Defense	Allergy (atopical eczema, allergy to the milk, rheumatoid arthritis)	Translocation, barrier effect
	Cariogenicity	Changes in the populations, activity of the oral microflora or its ability to adhere to the teeth
	Carcinogenicity, mutagenicity, tumor	Absorption of the mutagen, stimulation of the immune system, inhibition of carcinogen production by the intestinal microflora
	Diarrhea linked to antibiotics, diarrhea caused by Rotavirus, colitis caused by *C. difficile*, nosocomial diarrhea	Competetive exclusion, translocation/barrier effect, immune response promoted
	Helicobacter pylori	Antipathogenic activity
	Immunomodulation (immune status, vaccinal response)	Interaction with the immune cells or cell receptors leading to an increase in the phagocytic acivity of the white cells, increasing IgA levels after exposure to the antigen, increasing the proliferation of the intra-epithelial leukocytes, regulating the Th1/Th2 ratio, induction of cytokine synthesis
	Intestinal inflammation, ulcerative colitis, Crohn's disease, pouchitis	Immune response downregulated
	Excessive intestine bacterial growth	Antimicrobial activity, competitive exclusion
	Vaginosis, urinary infections	Antipathogenic activity, competitive exclusion
Others	Lowering of blood cholesterol	Deconjugation of the bile acids
	Endotoxemia combined with cirrhosis	Inhibition of the production of endotoxins by the intestinal microflora
	Hypertension	Cellular constituents or peptides derived from fermentation acting as inhibitors of ACE (angiotensin-converting enzyme)
	Renal calculi	Changes in the digestive flora influencing the breakdown of oxalate

for functional foods, especially functional dairy products, such as yogurts and fermented milks, containing *Lactobacillus* and *Bifidobacterium*.

Prebiotics are defined as nondigestible substances (dietary fiber) that exert some biological effect on humans by selective stimulation of growth or activity of beneficial microorganisms either present on therapeutically introduced to the intestine. Prebiotics undergo fermentation by probiotics in the large intestine. Prebiotics are sources of energy for probiotics. Clinical trials have shown that several different oligosaccharides can be used to stimulate bifidobacteria in the gastrointestinal tract and protect against gastrointestinal infections (Novak, Katz 2006).

Prebiotics are inulin, fructo-oligosaccharide, galactooligosaccharide and lactulose. With regard to a possible role for prebiotics in reducing the risk of diseases, the evidence is limited. The area where evidence can be considered promising is constipation (Roberfroid 2000) and gastrointestinal infections (Novak, Katz 2006). Although prebiotics improve calcium absorption (Abrams et al. 2005), their positive role in reducing the risk of osteoporosis needs to be supported by more human studies. The reduction of the risk of obesity and possibly of type 2 diabetes, both of which are known to be associated with insulin, also needs further investigation.

It has been observed that modification of intestinal microflora by inherently selectively fermented prebiotics is central in determining their nutritional properties (Van Loo 2004). Prebiotics interact positively through the large intestinal surface with various physiologic processes and are thought to improve health status by reducing risk for disease.

Probiotics, intestinal microflora and health

One of the main selection criteria for probiotics has been competitive exclusion of pathogens. Probiotics compete directly or delay the adhesion of pathogens on stereo-specific receptors on the mucosal surface of gastrointestinal tract. They also have an influence on the development of intestinal microflora in infants. The outcome of the microbiota development and competitive exclusion depends on the specificity of the microorganisms and their adhesion for the receptors and the relative concentrations of competing bacteria. The effective dosage of probiotics is thus determined by the relative affinity for receptor sites (Salminen et al. 2005). Different probiotics and even different strains have distinct modes of action and the clinical efficacy of various probiotics has been proven in distinct indications (Holst, Breves 2005).

Gut health and immunity

The gut and immune system form a complex integrated structure that has evolved to provide effective digestion and defence against ingested toxins and pathogenic bacteria. Around 60 % of functional foods, principally pro- and prebiotics, are targets of the gut and the immune system. A characteristic feature of gastrointestinal immune systems is its ability to exhibit tolerance towards innocuous dietary antigens and commensally microflora acquired during infancy and to mount a vigorous immune response to potentially pathogenic microorganisms. The execution of these disparate functions requires that the immune system surveys all the lamina antigens, to sort “harmful” from “harmless” antigens and to tightly regulate the ensign effect or responses; a failure to regulate the mucosal immune response results in a range of clinical disorders such as allergy, inflammation and autoimmune diseases (Gill 2003). To perform these functions the gastrointestinal tract harbours the largest immune system in the whole body, over 70 % of the total immune system being located in this area. The gastrointestinal immune system consists of two main components: organized lymphoid follicles (Payer's patches and mesenteric lymph nodes, and a large number of immunocompetitive cells – the organised tissues) serve as a potential site for the induction of immune responses to new antigens, whereas the intestinal mucus serves as the effector site.

Probiotics and the immune system

The effect of probiotics on the immune system has been the subject of numerous studies over the past 20 years. There is evidence that certain strains of probiotics are able to stimulate as well as regulate several aspects of the natural and acquired immune response. It has also been demonstrated that there are significant differences between the ability of *Bifidobacterium* and *Lactobacillus* strains to influence the functioning of the immune system.

The initiation, maintenance and resolution of both innate and acquired immune responses are regulated by cell-to-cell communication via cytokines. The intake of probiotics in humans has been shown to enhance cytokine production *in vivo*, and by peripheral blood mononuclear cells *ex vivo* (de Simone et al. 1989). Probiotic intake has been reported to be effective in restoring the age-related decline in phagocyte function (Gill 2003). Strain- and dose-dependent differences in the ability of probiotics to influence immune function are well documented (Gill 1998). The intake of specific strains of probiotics has also been shown to enhance humoral immune responses to natural infections and systematic or oral immunization in human subjects (Majamaa et al. 1995; Fukushima et al., 1998). It is important to note that probiotic administration is also known to stimulate antibody responses to completely unrelated antigens as well as to themselves (Yasui et al. 1989).

Probiotics are thus suggested to confer protection against enteropathogens by:

- stimulating cytokine production;
- enhancing the phagocytic capacity of polymorphonuclear cells and macrophages;
- augmenting NKH cell activity;
- enhancing specific antibody responses to pathogens.

Minimum concentration of probiotic required for beneficial effect

The information to recommend the minimum concentrations of probiotic bacteria for effective function is still insufficient. Nevertheless, adequate numbers of viable cells, namely the "therapeutic minimum" need to be consumed regularly for transfer of the "probiotic" effect to consumers (Viljoen 2001). Consumption should be more than 100 g per day of bio-yogurt containing more than 10^6 CFU ml^{-1}. Shah (2000) amongst others has suggested a minimum viable number of 10^6 CFU ml^{-1} or gram but recommends 10^8 CFU g^{-1} to compensate for reduction through passage through the gut. Yogurt is a classic example of a functional food with probiotics. Yogurt with probiotics, called bio-yogurt, should contain living bacterial cells. According to regulation yogurt should contain 2 ×

10^6 living bacteria in 1 ml at the end of the recommended storage period. The daily dose of probiotic microorganisms should reach 1×10^9 cells. The titre of bacteria in fermented drinks reaches 10^8 to 10^9 ml^{-1} and decreases with storage. It is also possible to use tablets or capsules as additives to foodstuffs, that contain lyophilised cultures of bacteria. Probiotics are available as pharmacopoeia preparations such as Linex 1.2×10^7, Mutaflor 2.5×10^9, Lactoseven 1×10^9. Jogurt capsules 2×10^9 contain freeze-dried bacterial cells per caps, correspondingly. The question is – which is more effective way to take viable or lyophilised bacteria – in yogurt or capsules? The intake of functional dairy products also is more physiologically and more acceptable for patients or consumers as well. Within the last decade, consumers have made increasing reference to functional food, recognising the relationship between nutrition and health to the point of endowing an overreliance on pharmaceuticals and regarding prescription drugs as often being unnecessary, too expensive, unsafe and of dubious benefit once all the risks are considered (Bagchi 2006).

Safety of probiotics

The safety of probiotics can be described in short:

(i) centuries of use fermented products;

(ii) no reports of probiotic pathogens;

(iii) safe use of active cultures in thousands of subjects have demonstrated that probiotic intake is safe.

This past safe history is very important regarding use by pregnant woman and newborn, because there is some limitation for clinical trials. At the same time, some scientists have doubt about reasonability in taking a high dose of viable bacteria (Henriksson et al. 2005). A review outlining the safety of current probiotic compounds has been published (Borriello et al. 2003). Cases of infection caused by *Lactobacillus* and *Bifidobacteria* are extremely rare. Previous research into the protective mechanisms associated with probiotic bacteria focused on the bacteriology of the gut and concentrated on intestinal colonisation and probiotic-induced suppression of pathogen growth and/or invasion (Clancy 2003). Indeed, the concept of a balance existing in the intestine, involving competition between probiotic and pathogenic bacteria for specific binding sites on intestinal epithelial cells, has been well established in the literature. However, recent research has turned toward understanding the role of probiotics and their products, and in enhancing and modulating innate and adaptive immune responses in the organism by other mechanisms (Fedorak, Madsen 2004). The ability of immune and epithelial cells to discriminate between different microbial species through activation of Toll-like receptors (Kadowaki et al. 2001; Vinderola et al. 2005) indicates that probiotics may show some of their protective functions through modulation of immune activity and epithelial function in gut.

Probiotics and selenium

Selenium (Se) has been recognized as an essential nutrient in the late 1950s, when it was found that it could replace vitamin E in the diets of animals (Schwartz et al. 1957). It is hard to overestimate the importance of Se to biological systems. Its crucial role is underlined by the fact that it is the only trace element to be specified in the genetic code (Rayman 2002). It is specified as selenocysteine, now recognized as the 21st aminoacid, as it has its own codon and specific biosynthetic and insertion mechanism (Gladyshev 2001). About 40 mammalian selenoproteins have been identified as having enzymatic redox activity, structural and transport functions. Thereby it is suggested that Se adequacy is crucial to human and animal health. A detailed review of Se deficiency symptoms, pathology and biochemical mechanisms was published by Gibson (2005). Low or diminishing Se status in some parts of the world, notably in Scandinavian and some other European countries, such as the UK, Baltic States, Croatia, Poland, Hungary, influences human and animal health. There is evidence that Se deficiency may contribute to development of a form of heart disease, hypothyroidism, and a weakened immune system (Combs, 2000; Zimmerman, Kohrle 2002). There is also evidence that Se deficiency does not usually cause illness by itself, because no one specific disease has been found, but it can make the body more susceptible to illnesses caused by other nutritional, biochemical or infectious stresses (Beck et al. 2003).

Epidemiological evidence in humans suggests a role for selenium in reducing cancer incidence and mortality, especially from prostate and colorectal cancer (Mantovani et al. 2004; Luty-Frackiewicz 2005; Finley 2006). The latest investigations show that Se administration decreases the toxicity of inorganic and organic forms of mercury (Cabanero et al. 2006). There are three arguments for increasing the Se intake: (i) Se deficiency may leave, than optimally protected against a number of adverse health conditions; (ii) Se intakes above those required to replete glutathion peroxidases and other selenoenzymes appear to confer additional health benefits and (iii) Se intake is low or marginal in many countries. Se enters the food chain through plants, but its incorporation is dependent not only on soil content, but also on the soil pH, rainfall, land profile, and activity of microorganisms (Combs 2001). Increasing Se intake from normal food sources is difficult to achieve. Meat and dairy products, eggs, Brazil nuts and wheat products are natural Se sources, but it is difficult to achieve the EU recommended 55 μg day^{-1} dose. Therefore it is necessary to perform food enrichment with dietary supplements of Se. Today situation is even more complicated because since August 1, 2005 dietary supplements containing organic Se forms are prohibited in the EU.

Our new project deals with the development of a novel type of functional food – Se enriched yogurt using probiotics able to concentrate Se intracellulary. It has been demonstrated that *Lactobacillus* accumulates some inorganic Se compounds in the form of selenocysteine (Calomme et al. 1995). Our experiments showed that supplementation of MRS broth (Sifin, Germany) with Bioenergostims Ultra Top (five inorganic Se compounds) promote yogurt starter cultures (*Lactobacillus bulgaricus* + *Streptococcus thermophilus*) growth at the Se concentration 100 mg l^{-1} till 15 % (Toma et al. 2006). Also, yogurt starter cultures become treatable to low pH in comparison with the control (Table 4). Supplementation with Se may stabilise membranes against the rigidity due to aging (Garcia et al. 2005). Preliminary experiments with fluorescent probe ABM (Kalnina et al. 2000) suggested an idea that the membranes of bacterial cells are selectively strengthened.

The combination of probiotics with Se in one product could confer benefits beyond those of either on its own.

Results with probiotic bacteria *Enterococcus faecium* demonstrate that the micronutrient selenium enhances the antimutagenic activity of probiotic bacteria (Križkova et al. 2002). It shows a potential benefit for the future development of new Se-enriched probiotic exhibiting higher antimutagenic properties.

Table 4. Effect of selenium on viability (log CFU ml^{-1}) of yogurt starter cultures after exposure to 0.2 M HCl-KCl buffer pH 2.5 (Toma et al. 2006)

	Time of exposure (h)		
	0	**1**	**2**
Control	9.9	6.1	3.5
Selenium (100 μg ml^{-1})	10.3	7.6	5.8

Probiotics and prebiotics as functional food

Probiotics and prebiotics simultaneously present in a product are called synbiotics. Such a combination aids survival of the administered probiotics and facilitates its inoculation into the colon. Additionally, the prebiotics induce growth and increase activity of positive endogenic intestinal microflora (Tomasik, Tomasik 2003). It was experimentally demonstrated that synbiotics protect the organism from carcinogens significantly better than do either probiotics or prebiotics separately (Gallaher, Khil 1999). Several foodstuffs with probiotics and prebiotics are available in the Latvian marketplace. One of the best is synbiotic yogurt Oat Bio Lacto (Bekers et al. 1999).

Summary

Probiotics can be considered functional foods because they provide health benefits beyond the traditional nutrition function. With few exceptions, most probiotic products currently available contain lactic acid bacteria, which mainly belong to the genera *Lactobacillus* and *Bifidobacterium*. The scientific papers published in major microbiological and nutrition journals suggest evidence of the following beneficial effects of probiotics: normalisation of the intestinal microflora, which both preserves and promotes wellbeing and the absence of disease (not only in the gastrointestinal tract), the ability to block the invasion of potential pathogens in the gut, prophylactic or therapeutic treatment for several types of diarrhoea (independently from aetiology), relief of symptoms of irritable bowel syndrome and inflammatory bowel disease, amelioration of lactose intolerance, prevention of colon cancer, inhibition of *Helicobacter pylori*, reduction of blood cholesterol level, hypertonia. Correction of the properties of unbalanced indigenous microbiota forms the rationale of probiotic therapy. However, an important part of the beneficial effects of probiotics are related to their immunomodulatory effects: immune chancing as well as anti-inflammatory activity. Bearing in mind the need for further evaluations, dietary modification towards a balanced dietary intake of nutrients and probiotics may offer a tool for both the management and risk reduction of allergic and autoimmune diseases.

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Probiotikas – funkcionālās pārtikas veids: mikrobioloģiskie un medicīniskie aspekti

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Kopsavilkums

Probiotiskās baktērijas satur galvenokārt fermentēti produkti, un tieši piena produkti kalpo kā probiotiku nesēji. Funkcionālie piena produkti ir ļoti piemēroti, lai sekmētu probiotiku atzīšanu veselības stiprināšanai šādu iemeslu dēļ: 1) fermentēta pārtika un sevišķi skābpiena produkti tiek lietoti veselības stiprināšanai jau gadsimtiem ilgi; 2) cilvēkiem nav iebildumu, ka skābpiena produkti satur dzīvus mikroorganismus; 3) piens, kas pats par sevi ir veselīgs produkts, plus probiotikas, kas tiek lietotas kā starta kultūras. Probiotikas ir dzīvu baktēriju preparāti (pārtikas produkti vai zāles), kam piemīt klīniski apstiprināta veselību uzlabojoša darbība. Vairumam probiotiku piemīt gļotādas barjeru un imunitāti uzlabojošas īpašības. Cilvēka zarnu traktā un zarnu mikroflorā probiotikām ir īpaši mērķi un uzdevumi. Probiotiku darbības mehānismu izpratšana (normālas zarnu mikrofloras uzturēšana, aizņemot savu nišu) var sekmēt probiotiku plašāku izmantošanu uzturā, samazinot atsevišķu saslimšanu risku. Daudz pētījumu liecina, ka ne tikai pro- un prebiotikas uzlabo imūnsistēmas darbību, bet arī atsevišķu mikroelementu iekļaušana funkcionālās pārtikas produktos var uzlabot imūnatbildi. Rakstā apkopoti jaunākie dati par funkcionālo pārtiku, probiotiku darbības mehānismiem un iedarbību, akcentējot labvēlīgo ietekmi uz veselību un īpaši uz imūnsistēmu.