

Market potential for probiotics¹⁻⁴

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ABSTRACT *Functional foods* as a marketing term was initiated in Japan in the late 1980s and is used to describe foods fortified with ingredients capable of producing health benefits. This concept is becoming increasingly popular with consumers because of a heightened awareness of the link between health, nutrition, and diet. Food manufacturers are enthusiastic about developing such products because the added ingredients give increased value to food. The global market for functional foods in the coming years is predicted to grow rapidly. Although Japan currently accounts for about one-half of this market, the fastest rate of growth is expected to be in the United States. Probiotic products represent a strong growth area within the functional foods group and intense research efforts are under way to develop dairy products into which probiotic organisms such as *Lactobacillus* and *Bifidobacterium* species are incorporated. Such probiotic foods may modulate gut microbial composition, thereby leading to improved gut health, for example, through improved tolerance to lactose in lactose-intolerant individuals or improved resistance to pathogenic bacteria. Large numbers of viable microorganisms are likely to be required in the food product, which should be consumed regularly to experience the health effect. The probiotic market, especially dairy products such as yogurts and fermented milks, has experienced rapid growth in Europe. The long-term exploitation of probiotics as health promoters is dependent on several factors, including sound, scientifically proven clinical evidence of health-promoting activity; accurate consumer information; effective marketing strategies; and, above all, a quality product that fulfills consumer expectations. *Am J Clin Nutr* 2001;73(suppl):476S-83S.

KEY WORDS Market, probiotics, functional foods, dairy products

INTRODUCTION

It is now well established that there is a clear relation between diet and health. Although the primary role of diet is to provide enough nutrients to fulfill metabolic requirements, more recent discoveries support the hypothesis that, beyond nutrition in the conventional sense, diet may modulate various functions in the body. Functional foods, of which probiotic-containing foods are a subset, have recently justified the efforts of health authorities in many countries, especially Japan and the United States, to stimulate and support research on the physiologic effects of food components and their health benefits and to authorize health claims.

Probiotics are described as single or mixed cultures of live microorganisms that when applied to animals or humans beneficially affect the host by improving the properties of the indigenous microflora. Probiotics are restricted to products that 1) contain live microorganisms (eg, as freeze-dried cells or in a fresh or fermented product), 2) improve the health and well-being of humans or animals (including growth promotion of animals), and 3) can affect all host mucosal surfaces, including the mouth and gastrointestinal tract (eg, applied in food, pill, or capsule form), the upper respiratory tract (eg, applied as an aerosol), or the urogenital tract [applied locally (1)]. Foods containing such bacteria fall within the category of functional foods, which are described as foods claimed to have a positive effect on health. Such products are gaining more widespread popularity and acceptance throughout the developed world and are already well accepted in Japan and the United States. Furthermore, increased commercial interest in exploiting the proposed health attributes of probiotics has contributed significantly to the rapid growth and expansion of this sector of the market.

The origin of the term *functional food* can be traced to Japan, where the concept of foods designed to be medically beneficial to the consumer evolved during the 1980s. The term refers to the practice of fortifying foods with added ingredients that can confer health effects on the consumer. Current definitions of what constitutes a functional food vary considerably as a result of the rapid growth of the area in recent years outside Japan. Furthermore, many of these terms have no legal definition. Functional food ingredients include probiotics, prebiotics, vitamins, and minerals and are found in such diverse products as fermented milk and yogurt, sports drinks, baby foods, sugar-free confectionery, and chewing gum (2). Probiotics are nondigestible food ingredients that beneficially affect the host by selectively stimulating the growth, activity, or both of one or a limited number of bacteria in the colon, thus improving host health (3). In Japan functional foods are considered a major product opportunity and >80 recognized

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functional foods are available (2). In 1991 functional foods were given legal status in Japan, where they are described as FOSHU, indicating foods for specific health use (2). A FOSHU is defined as a food expected to have certain health benefits and that has been licensed to bear a label to that effect (4). Proven scientific evidence of the health effect is a prerequisite to obtaining FOSHU status. It is worth emphasizing, however, that the health claims are limited to health maintenance and not the curing of disease. Functional foods as a category have enjoyed considerable growth and are now firmly established, with >300 firms operating in Japan.

In Europe, interest in functional foods has increased over the past several years as the market outside of Japan has developed. In particular, probiotic foods are now relatively well established in Europe and product activity during 1997 consisted of a more concentrated launch of prebiotic foods, particularly in the dairy sector. Although probiotic foods seem to be reasonably well established in Europe and Japan, they are typically considered niche products in the United States (5). It is expected that product development in functional foods could outstrip development in low-energy and "light" foods, which was a key area of growth in the early 1990s.

LEGISLATION ON FUNCTIONAL FOODS

In Japan the FOSHU food category includes such nutraceutical ingredients as peptides and proteins, n-3 and n-6 fats, and oils, sugar alcohols, oligosaccharides, and lactic acid bacteria (2). Popular among the ingredients included in the Japanese functional food group are oligosaccharides, for improvement of intestinal microflora or prevention of dental caries (6). In addition to approved FOSHU foods, many unapproved functional foods are available in Japan. These unapproved foods cannot carry an associated health claim but rely instead on consumer awareness of the probable health benefits of the ingredients.

The regulatory status and claims relating to the health-promoting properties of functional foods were addressed in Europe and the United States in the late 1990s (6, 7). Functional foods as they are known in Japan do not exist in either Europe or the United States because no regulation or policy statements exist specifically for them. Therefore, foods that could be regarded as functional foods are subject to regulations drawn up for other food groups. The US Food and Drug Administration (FDA) defined 4 food categories: conventional foods, constituting the largest category and including articles of food and drink that do not fall into the other 3 categories; foods for special dietary use; medical foods; and dietary supplements. The primary determinant of to which category functional foods belong is the intended use of the food. According to Berner and O'Donnell (6), "it is possible to envision 'functional foods' in any of the categories of foods and supplements mentioned above." Interest in functional foods is high in the United States, as reflected by the volume of news reports and conference announcements targeting *functional foods* and *nutraceuticals*, which are regarded by many as the current buzzwords in the food industry. In addition, US consumers are preoccupied with health issues, such as heart disease, cancer, and high blood cholesterol, and consequently desire foods that prevent or alleviate disease.

Currently in the United States, many producers of nutraceuticals are positioning their products in the medical foods category (8); thus, this category has grown dramatically in recent years. The main reason for this growth is that medical foods are exempt

from nutrition labeling; health claim regulations apply to conventional foods and foods for special dietary use (6). Medical foods include foods that are formulated to be consumed or administered entirely under the supervision of a physician. They are intended for the specific dietary management of a disease or condition for which distinctive nutritional requirements have been established on the basis of recognized scientific principles (9).

From a legislative standpoint, probiotic-containing foods could fit into several of the 4 categories of foods described by the FDA; however, there is no explicit recognition of any health benefits of probiotics, prebiotics, or cultures-added dairy foods in the United States (6). Conventional foods containing probiotic bacteria can be sold, but their labeling and marketing are regulated strictly by the FDA. At present, no direct health claims for probiotic cultures can be touted, which substantially restricts the industry. Indirect claims can be made, but these are of limited benefit. An example of an indirect claim might be "contains acidophilus and bifidobacteria, which are considered normal inhabitants of a healthy intestinal flora." In the United States, many yogurts contain *Lactobacillus acidophilus*, bifidobacteria, or both, which are mentioned in the list of ingredients, but often no information about the strains is available. These products are well positioned for the future, considering the growing awareness of probiotics among consumers. In addition, there are numerous consumer publications on the nutritional quality of yogurts and those that contain probiotic cultures are considered by some to be superior.

In contrast with the situation in the United States, the level of awareness and acceptance of probiotics and prebiotics in Europe is advanced, although in Europe as in the United States, neither a legal definition nor specific regulations governing functional foods exist. However, a distinction is made between medicinal products and foods for particular nutritional uses (PARNUTS foods). There is a strong interest among European consumers in foods claiming health benefits and a keen awareness of the relation between diet and health (10). Interest in health claims is likely to be high when the health claims are associated with conditions that generate a high degree of concern (eg, heart disease) or with conditions over which consumers feel they have a fair degree of influence (5). According to a study conducted by Leatherhead Food RA (11), there are differences in the health claims preferred by consumers in different European countries. This national variation in concern over health issues should be considered when planning a functional foods strategy for Europe. For example, whereas the UK consumer places great emphasis on claims related to heart disease (eg, "lowers cholesterol and blood pressure"), the German consumer is more interested in claims relating to general disease resistance.

Within the European Union, the marketing of functional foods is intimately connected with the issue of health claims. Functional foods in the European Union are those claimed to have health-promoting effects (7) and therefore are regulated by the Food Labeling Regulations. According to the directive relating to the "labeling, presentation and advertising of foodstuffs for sale to the ultimate consumer" (79/112/EEC), the manufacturer is not allowed "to attribute to any foodstuff the property of preventing, treating and curing a human disease, or refer to such properties" (7).

HEALTH ISSUES OF CONCERN

The health concerns of most interest to consumers that could be addressed by food products include osteoporosis, cholesterol,



heart disease, and general health (12). If consumers are to be the focus of the development of functional foods, products should be targeted toward these concerns. Consumer interest and belief in foods that may help prevent disease is growing, with 70% of American shoppers agreeing that some foods contain active components that reduce the risk of diseases and improve long-term health (13). This, together with consumer willingness to change dietary habits (97% of shoppers surveyed in the United Kingdom said that they are changing their eating habits to ensure a healthful diet; 14) indicates huge potential for functional foods.

Since Metchnikoff (15) first suggested that fermented milk could be consumed to eliminate putrefactive intestinal bacteria, there has been much interest in the possible health benefits of probiotic microorganisms. Many of the suggested benefits are based on the involvement of the gastrointestinal microflora in resistance to disease and the fact that the balance of the intestinal microflora can be affected by environmental factors and stress, thus compromising resistance. Probiotics may have a beneficial effect under such conditions. The potential clinical applications of probiotic bacteria are many and varied and reflect consumer concerns regarding health. Some of the clinical benefits associated with probiotics are based only on anecdotal reports and poorly controlled studies. Others, however, such as reduction of lactose intolerance and treatment of diarrhea, are well substantiated with scientific evidence. Some of the main therapeutic benefits attributed to probiotic microorganisms will be discussed here.

Lactose maldigestion, resulting from insufficient activity of lactase in the human gut, affects $\leq 70\%$ of the world's population, causing varying degrees of abdominal discomfort (*see* reference 16 for a review). Lactose in yogurt can be utilized more efficiently than lactose in milk, perhaps because of the preformed lactase in the yogurt or the presence of bacteria in the yogurt that produce lactase in the small intestine (16). More specifically, the beneficial effects of some β -galactosidase-producing probiotic bacteria such as *L. acidophilus* on lactose digestion have been shown (17, 18). The results of Lin et al (19) showed the importance of strain selection with respect to alleviating the symptoms of lactose intolerance.

In the United States, 21–37 million diarrheal episodes occur in 16.5 million children annually (20), with rotavirus being the most common agent of infantile gastroenteritis worldwide. The probiotic strain *Lactobacillus* GG was shown to promote recovery from rotavirus diarrhea in hospitalized children (21, 22) and reduce the duration of symptoms and of viral excretion in less severely ill ambulatory children (23). Other probiotic strains such as *Bifidobacterium bifidum* and *Streptococcus thermophilus* show preventive potential for diarrheal disease in infants (24). Furthermore, antibiotic-associated diarrhea was shown to be prevented by oral therapy with several probiotic microorganisms, including *Bifidobacterium longum* (25) and *Saccharomyces boulardii* (26).

Hypercholesterolemia has been clearly identified as a risk factor of cardiovascular disease and probiotic bacteria have been proposed as one means of lowering blood cholesterol concentrations in these patients. However, the role of lactic acid bacteria in reducing blood cholesterol remains controversial. Recent studies in humans showed that probiotic cultures can reduce blood cholesterol concentrations (27) and that there may be a preferential reduction in the LDL component of the cholesterol (28).

Evidence from studies in vitro and in laboratory animals indicates that lactic acid bacteria decrease the incidence of DNA damage (29) and other changes associated with the carcinogenic process

(30), suggesting an application for probiotics in protection against cancer. Furthermore, there is evidence that lactic acid bacteria can decrease the activity of fecal enzymes involved in the conversion of procarcinogens to carcinogens. For example, consumption of lactobacilli was associated with decreased activity of fecal β -glucuronidase, nitroreductase, and azoreductase (31, 32). Initial studies of the effects of probiotics in the area of cancer prevention in humans are promising, particularly for bladder cancer (33).

Overall, sufficient positive results indicate that probiotics have beneficial health effects. However, there is a need for well-designed, randomized, placebo-controlled studies in humans to provide sound scientific evidence of these effects. Also, some health benefits may be strain dependent, stressing the importance of probiotic strain selection.

PROBIOTIC FOODS

In Japan a standard was developed by the Fermented Milks and Lactic Acid Bacteria Beverages Association stipulating that a product contain $\geq 1 \times 10^7$ viable bifidobacteria/g or mL product to be considered a probiotic food (34). However, the minimum amounts required and the optimal period of administration of probiotics needed to elicit a health effect remain unclear (35). A therapeutic minimum dose of 1×10^5 viable cells/g or mL product was proposed (36). However, the minimum dose required for a probiotic effect may be dependent on the food form in which the probiotic is ingested (37) and probably on the probiotic strain used.

To successfully develop food products containing these concentrations of probiotics, a thorough knowledge of the abilities of the microorganism to survive the manufacture and storage of the product is required. To be beneficial in the host, dietary cultures must reach the gastrointestinal tract (the target organ) in significant numbers, which requires that they survive harsh conditions, including acid in the stomach and bile in the small intestine. When strains are selected for incorporation into a particular food, factors such as the ability of the microorganism to survive passage through the gastrointestinal tract, survive the food manufacturing process, and grow and survive during the ripening or storage period are of utmost importance. Furthermore, the added probiotic bacteria must not negatively affect product quality, be generally recognized as safe (GRAS), and preferably be of human origin. Yogurt and fermented milks have received the most attention as carriers of live probiotic cultures, whereas other dairy foods such as some cheese varieties, frozen yogurts, and ice cream have been investigated as potential carriers (*see* reference 38 for a review). Cheddar cheese has been studied as a potential probiotic food and was shown to be capable of supporting the viability of some strains of *Bifidobacterium* (39) and *Lactobacillus* (40), without having any adverse effects on cheese flavor, texture, or appearance. The food delivery system has an important role in determining the viability of the organism after consumption (41) and cheese compares favorably with yogurt as a vehicle for delivery of high numbers of viable probiotics to the gastrointestinal tract (38).

THE MARKET FOR FUNCTIONAL AND PROBIOTIC FOODS

The most active area within the functional foods market in Europe has been probiotic dairy products, in particular, probiotic yogurts and milks. In 1997 these products accounted for 65% of the European functional foods market, valued at



US\$889 million, followed by spreads, valued at US\$320 million and accounting for 23% of the market (11). In a recent study undertaken by Leatherhead Food RA, the market for functional foods in the United Kingdom, France, Germany, Spain, Belgium, Netherlands, Denmark, Finland, and Sweden was reviewed. The results of the study showed that the probiotic yogurt market in these 9 countries totalled >250 million kg in 1997 (11), with France representing the largest market, having sales of ≈90 million kg, valued at US\$219 million. The German market for probiotic yogurts is growing rapidly; for example, during 1996–1997, it increased by 150%, whereas the UK market grew by a more modest 26% during the same period. On average, probiotic yogurts accounted for ≈10% of all yogurts sold in the 9 countries studied, with Denmark having the highest proportion (20%) of probiotic yogurts, followed by Germany and the United Kingdom (both at 13%) and then France (11%). On the lower end of the scale were the Netherlands and Belgium (both at 6%) and then Finland and Sweden (both at 5%) (11). Seen as crucial to market expansion in Europe is further clarity on the use of health claims. The market for functional foods in Europe could ultimately account for ≈5% of total food expenditure in Europe, which, based on current prices, would equate to ≈US\$30 billion (5).

Soft drinks, the original functional foods, still dominate the Japanese market; dietary fiber and probiotics are the significant functional ingredients in many of these products. Bikkle, considered to be the quintessential functional drink, was launched in 1993 by Suntory (Osaka, Japan) and contains bifidobacterial cultures, whey minerals, xylooligosaccharides, and dietary fiber. This product achieved sales of 11 billion yen in its first year. Interestingly, the fermented milk drink Yakult (Yakult, Japan), which is classified as a functional food in Europe, is not regarded as such in Japan because the presence of probiotics in isolation from other functional ingredients does not carry functional food status in Japan (5). In addition to functional drinks, functional milk products and products for children are also important, with innovations in a variety of foods and drinks such as ice creams, confectionery, biscuits, snack foods, and calcium-fortified drinks. There have been several developments in the dairy products category, including the development of yogurts supplemented with oligosaccharides and calcium (5). It is expected that prebiotics and probiotics will continue to be among the major functional food ingredients for the foreseeable future in Japan. Estimations of the size of the functional foods market in Japan are made difficult by the lack of a clear boundary between health foods and functional foods, but current estimates are in the range of US\$3–3.5 billion.

The US functional foods market is comparatively underdeveloped by European standards, with fortified dairy products, particularly those containing active cultures, gaining popularity only recently. In contrast with the situation in Europe, there is a notable lack of development of prebiotics in the United States. Vitamin- and mineral-enriched products continue to be among the more successful functional foods in the United States. Market development has been held back by criticism leveled at companies that have introduced products bearing vociferous health claims. It is predicted that the US market for functional foods will experience the fastest growth rates compared with other countries in the future (5). An important aspect in this context will be the development, clarification, and testing of the laws relating to health claims. As is the case in Europe, the issue of health claims

will be important for the future growth and expansion of the market for probiotics and functional foods in the United States.

Leatherhead Food RA's 1996 report valued the global market for functional foods at US\$6.6 billion in 1994, with Japan accounting for just under one-half of that. Forecasts suggest that the market will have reached US\$17 billion by 2000, with the long-term potential to become as big as the low-fat and low-calorie markets, which are estimated to be in excess of US\$87 billion.

PRODUCT DEVELOPMENT

The key focus of the functional foods market in Europe has been the development of probiotic and prebiotic dairy foods, whereas in the United States, vitamin and mineral fortification of foods in general has been the key area of development. As consumers become more familiar with probiotics, the demand for these products will grow. Manufacturers will respond by introducing new products that will add value to their existing portfolios. The differences in the approach to functional foods in various countries have resulted in several different but related developments.

Dairy products, accounting for 65% of the total European functional foods market, are at the forefront of probiotic developments (11). Within this sector, probiotic cultures have been incorporated in yogurts and fermented milk products; of these, LC1 (Nestlé, Vevey, Switzerland), Vifit (Campina Melkunie, Zaltbommel, Netherlands), Actimel (Danone, Paris), and Yakult have emerged as the market leaders (11). Of all the dairy markets, that for yogurt, with its existing health image, is well positioned to capitalize on the growth in healthful foods. Yogurt additionally benefits from being a food that tastes good and is enjoyable.

The introduction of probiotic products has fueled growth in the German yogurt market, with sales of probiotic products increasing from DM130 million to DM300 million between 1996 and 1997. The leading brand in the sector is LC1 from Nestlé, with a 60% market share, ahead of Actimel from Danone with a 25% market share and followed by Mueller's Procult brand (Mueller, Germany). Germany exports 10% of its fruit yogurt output, of which 22.9 million kg is sold in the United Kingdom, where the market is estimated to be worth £575 million. Campina, one of the manufacturers responsible for some of this production, built on their success in the Netherlands and their home market when they launched Vifit, a live culture brand yogurt, in the United Kingdom in 1996. The main objective was to deliver a product of superior taste and eating quality that consumers would view as an integral part of their regular eating regimen rather than as a health supplement. The UK launch came with a £3 million marketing package, which earmarked £2 million for a national advertising campaign for the 16–34-y-old audience. In addition, the marketing included consumer press advertising, special trial sizes, in-store tastings, a customer help line, and price promotions.

Since its launch in 1996 on the UK market, Yakult, the fermented milk drink "containing beneficial live bacteria" has more than doubled its sales, securing a £7.2 million niche in the yogurt and ready-to-eat dairy dessert market. Based on this performance, all the major retail outlets have moved to national distribution of the product. The money spent on advertising is expected to continue, in addition to sampling of >1 million bottles in stores, communities, and workplaces.

Although there is no specific legislation on functional foods, existing laws on misleading claims and food safety are being



enforced. One firm to be affected by these laws is the Danish dairy company MD Foods, which launched Gaio yogurt, a cultured dairy product for which cholesterol-reducing properties were claimed. In response to complaints lodged by a consumer organization to the Advertising Standards Authority that the claim was exaggerated and misleading, the product was withdrawn in January 1997 (5).

Nestlé's LC1, available either as a set cultured milk or as a drinking product, contains the *L. Tacidophilus* strain La1. This *Lactobacillus* strain, chosen for its probiotic characteristics, has been researched extensively by Nestlé. On the basis of human studies, this culture is claimed to stimulate the immune system, leading to the statement, "helps the body protect itself" (5). The product was launched in France in 1994 and is currently available in most European countries. By 1996, LC1 had seized a 15% share of the French bioyogurt market and, even within the traditionally skeptical UK market, accounted for 20% of the company's European trade in yogurts and fermented milks (5).

In Switzerland a "probiotic enhanced" yogurt called SymBalance (ToniLait AG, Bern, Switzerland) was recently introduced that contains the prebiotic inulin as an enhancing agent and 4 human probiotic strains, including *Lactobacillus reuteri* (42).

FACTORS CRITICAL TO THE SUCCESS OF FUNCTIONAL FOODS

Interest in and acceptance of functional foods is gaining momentum for several reasons, including the development of new food processing, retailing, and distribution technologies; changing consumer demands and social attitudes; scientific evidence of health benefits of certain ingredients; and the search for new opportunities to add value to existing products and to increase profits. The market for functional foods within the dairy sector is under pressure from many different forces, including the need for constant research and development, competition from other products of the same brand, and changing target markets. If market needs and expectations are to be fulfilled, processors must liaise with food retailers to ensure that they are fully aware of changing consumer demands. Relationships of this nature will help ensure that new product introductions are in line with, or in anticipation of, shifts in market demand.

A strong health claim or inference, although being an important purchase motivator, does not guarantee a product's success. The customer must be encouraged to repeat the purchase, which may not happen if he or she cannot measure the benefits of the product. If the product can offer something measurable to the consumer in the long term, there is a greater chance of repeat buying. It is imperative that new products encompass a careful blend of price, market positioning, advertising, and an understanding of local market conditions and consumer attitudes. In addition, of course, the foods must be of excellent quality.

Changing consumer demands influence purchasing behavior. The quest for convenience is a driving force in the food industry. This has arisen as a result of both increasing numbers of women working and changing household structures, with more people living alone and having more active lifestyles. Consequently, there is less time to prepare food in the family meal setting. Additionally, consumers with increasing levels of education and

affluence will search for high-quality and healthful foods with added value. Consumers will demand convenience not only in terms of the product itself but also in the shopping environment. Similarly, as the pace of life increases, the tendency for consumers to snack between and instead of meals will grow (43). These increases in eating occasions or grazing will help to propel portable, hand-held foods into the fastest growing sector of the food industry. Vending machines, convenience stores, and other creative distribution mechanisms will play key roles by 2020 (43). Processors must take account of changes in taste and social attitudes in their overall marketing strategy.

Consumers are continually bombarded with both direct and indirect messages to focus on healthful foods and nutrition (44). As a result of the continued repetition of this message, diet and health have been inextricably linked. Consumer knowledge of nutrition, although not yet perfect, is improving and today's consumers find greater meaning in nutritional messages. Consequently, the marketing of functional products requires a 2-fold strategy. First, it is imperative that these new products fit the consumers' lifestyles and beliefs for future health goals (44). Second, the most appropriate market segment must be targeted.

THE FUNCTIONAL FOOD CONSUMER

Consumer research has identified several common characteristics of functional food purchasers, including being predominantly female, well educated, high earners, aged 35–55 y, and actively interested in health (*see* reference 44 for review). This research indicates that women hold stronger beliefs than do men in the health benefits of foods, as do persons with high incomes. Furthermore, there is a positive relation between belief in the health benefits of nutraceuticals and education level, which may be interrelated with higher income (44). Gilbert (45) identified functional food consumers as being somewhat older and better educated than the general population, although there is a growing belief in the concept of functional foods and nutraceuticals throughout the population (44). This trend is, in part, a result of consumers' advancing age and their having to cope with growing health concerns, as well as the increasing costs of health care. Experiences with their own parents' loss of good health will result in increasing concern with disease prevention; thus, functional foods with effects on aging, energy level, immunity, and to some extent treatment of disease will get primary attention. Furthermore, the population segments most concerned about nutrition, ie, women aged >40 y, will continue to expand. It is expected that 29 y from now, marketing food products for disease prevention and treatment will be commonplace. Marketers will be directing food products to new generations of young adults who have grown up more conscious of existing health problems and risk factors for coronary artery disease and cancer (43).

POTENTIAL OF PROBIOTICS

Food companies will continue to research new functional food products, resulting in the association of more food ingredients with health claims. Further product launches are expected in several areas, including sport-related products, fortified foods and drinks, and dairy products such as yogurts, cheese, ice cream, and milks containing prebiotics and probiotics. Although the market is right for functional foods, continued growth and success are heavily dependent on scientific substantiation.




The rate of increase in resistance to antibiotics (46) is a major public health problem throughout the world (47). Given the heightened concern over antibiotic resistance, natural alternatives such as probiotics for inhibition of pathogens are becoming more attractive. In fact, the World Health Organization recommends global programs to reduce the use of antibiotics “in animals, plants and fishes, for promoting livestock growth” and in human medicine and recommends increased efforts to prevent disease through increased immunization with existing vaccines and through the development of more effective and safer vaccines. In addition, several older forms of therapy, including bacterial interference, serum therapy, and the use of macrophages to kill organisms, may be worth reconsidering (47).

Some probiotic strains were shown to inhibit the growth of enteropathogens, such as *Salmonella enteritidis*, enterotoxigenic *Escherichia coli*, and *Serratia marcescens*, in vitro (48, 49) and in this respect may offer considerable therapeutic potential. This finding, together with more recent evidence showing that *Lactobacillus* GG exerts antagonist activity against *Salmonella typhimurium* C5 infection both in vitro and in vivo (50), provides a basis for the clinical use of probiotics in suppression of pathogens. Furthermore, the immunostimulatory properties of probiotics (51) offer potential in boosting the host's resistance to disease, thereby potentially reducing the frequency of antibiotic use. Other potential clinical applications for probiotic microorganisms include treatment of food allergy (52), reduction of hypertension (53), and use as vectors for delivery of oral vaccines (54), which would require the use of food-grade genetic markers (55, 56), as opposed to antibiotic-resistant genes, for their construction.

In addition to the role of oral probiotics in maintenance of health in humans, emerging evidence suggests that some probiotic strains, particularly *Lactobacillus* strains, may protect the urogenital tract against microbial infections (57–59). Furthermore, it was shown that some probiotic microorganisms can reduce the risk of infections associated with the use of medical devices (57–59). Additionally, the use of probiotics was proposed by several investigators as an alternative to antibiotics in animals (41, 60–62) and poultry (41, 63).

Another potential application of probiotic cultures is in the production of fermented food products enriched in health-promoting substances, such as conjugated linoleic acid (CLA). The term CLA refers to a mixture of positional and geometric isomers of linoleic acid involving double bonds at positions 9 and 11, 10 and 12, or 11 and 13, in addition to geometric variations of *cis-cis*, *cis-trans*, *trans-cis*, or *trans-trans*. CLA has gained considerable attention in recent years because of its many beneficial effects, including anticarcinogenic activity, antiatherogenic activity, the ability to reduce the catabolic effects of immune stimulation, the ability to enhance growth promotion, and the ability to reduce body fat (see reference 64 for review). Of the individual isomers of CLA, *cis-9*, *trans-11*-octadecadienoic acid was implicated as the most biologically active and is also the predominant isomer found in the diet, arising from microbial biohydrogenation of dietary linoleic acid to CLA in the rumen (65). Foods that contain animal fat, such as beef, lamb, milk, and dairy foods, are therefore rich sources of CLA (64). Certain strains of propionibacteria, commonly used as dairy starter cultures, were shown to be able to convert free linoleic acid to CLA (66), suggesting that it may be possible via fermentation to produce fermented food products enriched in CLA.

CONCLUSIONS

The development of successful probiotic products will be contingent on both proof of a probiotic effect and the development of foods that harbor high numbers of viable organisms at the time of consumption. Even though many health benefits are associated with the use of probiotics, research into the mechanisms by which these cultures exert their effects is still at an early stage. Consequently, continued scientific endeavors aimed at understanding at a cellular level the health-promoting effects of probiotic cultures should be seen as a crucial requirement for securing the future of probiotics as functional food ingredients. 

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