Biblid: 1450-5029 (2008) 12; 3; p. 97 - 100 Pregledni rad
UDK: 664 Review

FUNCTIONAL FOODS: TRENDS, PROSPECTS AND CHALLENGES FOR THE FOOD INDUSTRY
FUNKCIONALNA HRANA: TRENDOVI, IZGLEDI I IZAZOVI ZA INDUSTRIJU HRANE

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SUMMARY

Consumers currently demand that food products offer not only organoleptic qualities (e.g. taste) but also health benefits. Efforts for new product development are being directed towards the newly emerging area of 'functional foods'; these are products with health enhancing properties beyond the provision of essential nutrients. Functional foods can take many forms; some may be conventional products with bioactive components and other may be fortified to reduce disease risk for a certain group of people. Research currently underway at academic, industry and government facilities reveals how numerous constituents can serve as functional ingredients in food matrices or as supplements-remedies in pure form (nutraceuticals). Constituents from conventional and non-traditional plant and animal sources offer indeed unlimited opportunities for the creation of acceptable and marketable functional products. The future of functional foods will strongly depend on further advances of our knowledge in structure-function relations of food bioactives, innovative technologies for effective formulation and delivery of bioactives to different parts of the digestive system, enhanced sensorial quality and shelf-life of the product, establishment of proper regulatory framework to facilitate labelling claims and improved consumer understanding of health related benefits. This review paper aims to discuss the key issues surrounding the functional foods arena by considering the definition, the bioactive components, the development and the market drivers of functional products as well as the trends, opportunities and challenges the food industry faces on its way to translate basic-applied nutritional research and technology innovations (e.g. microencapsulation, nanoparticle technology, active packaging, etc.) into safe and health benefiting products for the consumer.

***Key words**: functional food FF, nutritional concept, functional ingredients, technology innovation.*

IZVOD

Potrošači stalno zahtevaju od hrane da pruži ne samo organoleptički kvalitet (na primer ukus), nego da je korisna za zdravlje. Napori koji se ulažu u razvoj novog proizvoda su usmereni na pojavljivanje nove oblasti označene kao "funkcionalna hrana"; to su proizvodi sa povećanim osobinama koje pozitivno utiču na zdravlje, a pri tome imaju i dalje esencijana nutritivna svojstva. Funkcionalna hrana ima više oblika; to može biti konvencionalna hrana sa bioaktivnim komponentama ili može biti "ojačana" tako da smanjuje rizik pojave neke bolesti za određene grupe ljudi. Istraživanja koja se trenutno izvode na akademskom i industrijskom nivou,ili na nivou državnih organa, obelodanjuju kako brojni konstituenti mogu da služe kao funkcionalni sastojci u matrici hrane ili kao dodaci u hrani i to u čistom formi. Sastojci iz konvencionalnih i netradicionalnih biljnih i životinjskih izvora, zaista nude neograničene mogućnosti za kreiranje prihvatljive i marketinški opravdane funkcionalne proizvode. Budućnost funkcionalne hrane će strogo zavisiti od daljeg unapređenja našeg saznanja. o strukturi i funkcionalnim odnosima hrane i bioaktiva, od inovativnih tehnologija za efektivnim formulacijama i mogućnostima bioaktivnih materija da se "dostave" do određenih delova digestivnog sistema, od povećanja senzorskih osobina i dužine vremena skladištenja "shelf-life", od ustanovljavanja zakonske regulative koja treba da obezbedi odgovarajće označavanje takve hrane i od povišenog nivoa obaveštavanja potrošača o njihovomn zdravlju i korisnosti primene funkcionalne hrane. Ovaj pregledni rad ima za cilj da diskutuje o ključnim tačkama u vezu funkcionalne hrane, da uzme u obzir definiciju ovog pojma, bioaktivne komponente, razvoj i tržište funkcionalnih proizvoda, kao i trendove, mogućnosti i izazove sa kojima se susreće industrija hrane na svom putu prenošenja fundamentalnih i primenjenih rezultata istraživanja u inovacione tehnologije (na primer mikroenkapsulacija, tehnologija nano čestica, aktivno pakovanje i dr) koje će obezbediti zdravstveno bezbedne proizvode za potrošače.

***Ključne reči**: funkcionalna hrana FP, concept ishrane, funkcionalni sastojci, tehnološke inovacije.*

INTRODUCTION

During the last decade the nutritional science has developed new views on the role of the diet beyond basic requirements for normal body functions[1]. This increased awareness of the physiological activity of food components and their role in our well-being has fostered the introduction of functional foods (FF). The populations of most developed countries are rapidly aging. In spite of the increase in health consciousness, a growing number of adults suffer from the so-called diseases of affluence. As a result there is a growing interest in the potential for using diet to lower the risk of chronic diseases like coronary heart diseases (CHD), cancer, osteoporosis etc. Even younger people with busy lifestyles are keen to invest in the personal health making choices for quick and convenient meals that help to maintain their well-being or even prevent illness and at the same time, taste good. The development and marketing of FF is the food industry's response to the consumers' demand for foods that are both attractive and healthy. Of course, food means different things to different people, and taste, convenience, extended shelf-life, safety and health all play an important role in influencing food choices consumers make on a daily basis.

DEVELOPMENT OF FUNCTIONAL FOODS

It is important to note that the concept of FF did not develop quickly; instead, they can be viewed as products of a multi-step evolution process with discrete achievements in the post-harvest food technology field[2]. In the 70s, foods were first introduced that were less processed to approach the wholesomeness of raw materials and this trend was followed by products enriched with vitamins (e.g. milk fortified with vitamins A, D) to improve health. In the 80s, it was recognized that over-consumption of calories from fat and carbohydrates was a major contributing factor, along with the lack of exercise, to the higher incidence

rate of obesity and other chronic diseases. This resulted in the development of food products that were "less- evil" (low fat, low sugar, reduced salt and cholesterol-free products) and marketed with relevant food labeling information to make food choices easier for consumers. In the 90s, new initiatives were brought forward to generate products with specific functions following scientific advancements in the nutritional sciences field on the links between food and health; these foods, known as functional foods (FF), contain specific value-added ingredients (also known in isolated forms as "nutraceuticals") that may act to prevent diseases and enhance the health and wellness of consumers.

DEFINITION OF FUNCTIONAL FOODS

There is a great deal of controversy about how FF can be distinguished from conventional foods. For example, for most consumers, orange juice is orange juice. However, this product, being the subject of several clinical studies which demonstrate that its flavonoids can change favorably the human lipid profile upon consumption, is viewed as FF. The definition of FF is a contentious issue and most regulatory agencies do not recognize FF as a nutritional entity. Even in Japan, where FF originated, the term itself is not adopted because it is agreed that "all foods are functional"[3]. Generally, FF can be defined as "*any food product that is marketed or perceived to deliver a healthy benefit, in addition to its basic nutritional value*". To distinguish between FF and nutraceuticals, the latter according to Health Canada are defined as "… products derived from foods and sold as powders, liquid extracts, pills or other medicinal forms that are not generally associated with food, but they do demonstrate physiological benefits or protection against chronic diseases". In Japan, the definition of FOSHU ("Foods for Specialized Health Use") provides the essence of what makes a food functional: "*A food (not a capsule, tablet or powder) derived from naturally occurring ingredients that can and should be consumed as part of the daily diet*". This definition states that FF provide certain functions when consumed, related to regulation of body processes such as : (a) enhancement of biological defense mechanisms, (b) prevention of a specific disease, (c) recovery from a specific disease, (d) control of physical and mental conditions, and (e) slowing the aging process. It is worth noting, however, that "prevention of disease" is classified as a drug claim in the US, Canada and other countries.

Overall, FF exists in many forms. Raw foods can be functional if they contain endogenous constituents with well proven health benefits (e.g. tomatoes rich in lycopene that may reduce the risk of prostate cancer). Processed tomato products or many cereal-based foods (known for lowering blood serum cholesterol and modulating postprandial blood glucose and insulin levels) as well as beverage-formatted drinks with phytosterols (clinically proven to reduce cholesterol) or calcium-enriched orange juice (for reducing the risk of osteoporosis), can all be classified as functional.

FUNCTIONAL FOOD DEVELOPMENT AND MARKETING

The development and marketing of functional foods is driven by a number of key factors (Fig. 1). An increasing number of consumers are becoming more aware that illnesses such as CHD, diabetes, obesity and even certain types of cancer are diet-related. There is also increased number of aging people who consciously are taking the responsibility for managing the health problems by watching their diets. Moreover, there is considerable pressure on governments and healthcare organizations to reduce hospitalization and healthcare costs; i.e. better to "prevent" rather than "cure". For example, it has been estimated that consumption of phytosterol-fortified foods has the potential of saving $150 million/year in healthcare cost in UK alone. Clinical support for proof of efficacy coupled with commercially-feasible technological solutions, are also critical issues in the development of successful functional products. In this respect, product differentiation is important to promote growth and improve the market share of a company.

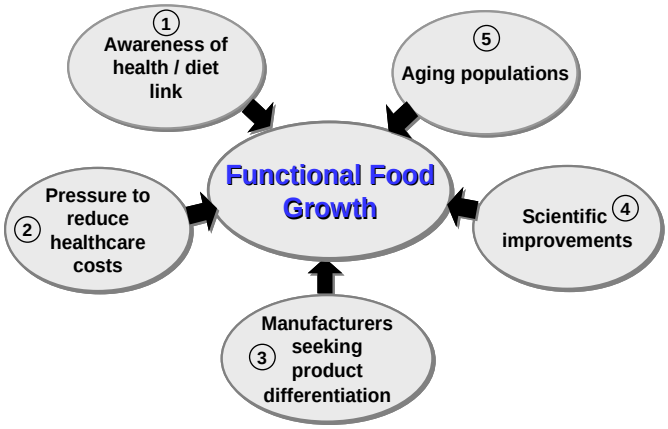

Fig. 1. Market drivers for Functional Foods (adapted from ref. 2).
Sl. 1. Zahtevi tržišta postavljeni pred funkcionalnom hranom (1. bojazan za zdravlje – dijete; 2. zahtevi za smanjenje troškova zdravstvene zaštite; 3. zahtevi proizvođača funkcionalne hrane za promociju različite hrane; 4. zahtevi za naučnim i kliničkim potvrdama o funkcionalnoj hrani; 5. zahtevi starije populacije za hranom koja rešava neke zdravstvene tegobe)

Overall, FF development involves several distinct stages from concept to successful market implementation under the synergistic alliance of various stakeholders, representing research, industry, regulatory and consumer interests[4]. The process is depicted in Fig. 2 and usually commences from the creation of an idea of a novel diet-disease concept. Such concepts may originate from research performed in industrial or academic environments and could arise from a massed evidence or from previous similar successful processes (products). Teams of academics working closely with business interests provide the grounds for taking forward an optimal concept product through the successive elements of the innovation cycle. Following concept generation, the next step is to develop a real-world test product that embraces the concept; this may represent a considerable challenge in formulation strategies or processing and stability issues (e.g. incorporation of ω-3 fatty acids in an aqueous phase of a product, the introduction of phytosterols in a fat spread or the production of a probiotic-enriched yoghurt with live culture). In many instances, the product and processes must be carefully designed to possess acceptable organoleptic qualities. Expression of the nutrition-health concept in the formulated product needs to be verified through testing of its biological efficacy. The reasons to test for physiological action of bioactive ingredients in properly designed food matrices are several. Stability - delivery through the digestive tract and absorption processes of bioactives are all influenced by the food matrix. For example, among several products fortified with plant sterols, the milk matrix, compared to bread, cereal and yoghurt, was shown three times more effective as a food delivery system to reduce LDL cholesterol levels[5]. Moreover, the requirement for a minimum (threshold) dosage to achieve biological efficacy may not be met with an inappropriate matrix throughout the digestion process. Champagne *et al*.[6] commented on the survival issue of probiotic bacterial during passage through the acidic environment of the stomach; this constitutes a major concern to manufacturers of fermented foods with probiotic cultures. It is also a challenge to conduct efficacy assessments with *in vitro* or *in vivo* systems. Cell systems provide basic metabolic information on cellular responses to the addition of bioactive compounds. However, there

is often a need to establish a whole body of physiological evidence using animal or even human systems by properly conducted clinical trials. Confirmation of efficacy with human studies indeed provides strong evidence to support health claims that are product specific. Dissemination of the observed physiological activities of bioactives through publications in peer-reviewed journals is the most widely accepted avenue to distribute new knowledge and to create an interest and positive position for a given functional food ingredient.

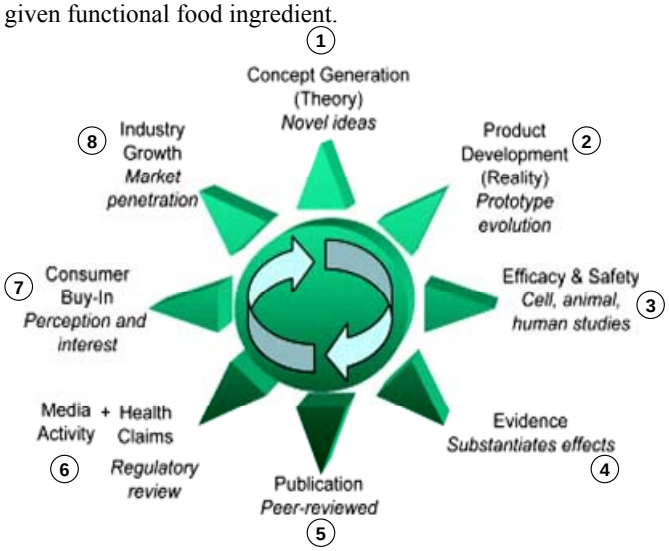

*Fig. 2. Functional Foods and the promotion of new nutritional concepts – cycle of innovation (adapted from ref. **4**).*
Sl. 2. Ciklus potrebnih inovacija (aktivnost) za promociju novih nutritivnih koncepata i funkcionalne hrane – FH
(1. generalni koncept – nove ideje; razvoj proizvoda putem stvarnih troškova; 3. sigurnost i uspešno dejstvo (istraživanja na nivou ćelije životinja i ljudi); 4. dokazi o različitim efektima; 5. publikovanje naučnih dostignuća; 6. prenošenje novih saznanja putem medija, zakonske regulative; 7. zainteresovanost kupaca; 8. rast industrije FH – dostupnost na tržištu)

Communication of the health messages generated from research and compliance with regulatory issues are the next steps in the innovation cycle. Globally, the regulatory systems vary widely with some countries like Japan allowing currently over than 500 FF, while other countries such as Canada and the European Union posing strong restrictions on health claims. Regardless of the restrictions imposed in different jurisdictions, the process of regulatory review shares common features, by focusing on the provision of sound peer-reviewed research data for efficacy and safety and their compliance to a set of criteria-requirements for permission of a certain health claim. Given that consumer perception and interest about the product is generated, the stimulation of the market and the placement of the industry on a competitive edge will close the innovative cycle. This will further stimulate additional 'concept-ideas' to be taken through the multiple elements of a new cycle and strengthen the growth and sustainability of the food industrial sector.

SOME EXAMPLES OF KEY FUNCTIONAL INGREDIENTS – FUNCTIONAL FOODS

Phytosterols and *phytostanols* are lipid-like compounds found in the vegetable oils and coniferous trees; these plant constituents are chemically similar to cholesterol and they exhibit competitive inhibition of intestinal absorption of cholesterol. Numerous clinical studies support that both sterols and stanols as well as their fatty acid esters have similar abilities to lower total cholesterol by 7-9% on ingestion of 3-6 g/day. Most of the published data indicate that a daily intake of 2-3 g of phytosterols also lower the low-density lipoprotein (LDL) – cholesterol concentration by 10-15%[2,7]. At this level of LDL lowering, a reduction in heart disease risk of 25% would be expected in the general population. There are at least three possible mechanisms of action for phytosterol – induced lowering of serum cholesterol, and additional protective effects on proliferation of colonocytes (linked with reduced cancer risk) have been also suggested.

Sterols and stanols are presently found in many functional products including fat spreads, yoghurts and other fermented dairy and non-dairy products, rye bread, etc., and over the past 5-7 years a number of health claims have been approved for these products in US, Canada, Australia, Japan and Europe[2,8]. Sterols and stanols are generally recognized as safe, with one important concern related to the potential interference with absorption of fat-soluble nutrients (e.g. carotenoids) if consumed in large amounts daily. Overall, it is generally accepted that the consumption of 1-2 g of sterols daily will lead to beneficial effects in lowering serum cholesterol and LDL-cholesterol levels without causing any adverse effects.

Dietary fiber is the endogenous part of plant materials in the diet that resists to digestion by human enzymes found in the gastrointestinal (GI) tract. It mostly includes cellulose, hemicelluloses and other mucilages-gums, pectins and lignin. All these poorly digested materials by humans seem to have a number of beneficial physiological effects in the digestive tract. Dietary fibers are classified as soluble and insoluble. The use of the soluble fiber (β-glucans) from oat bran in cardiovascular risk management was the first health claim allowed under the US Dietary Supplement Health Education Act in the early 90s. There are now specific β-glucan claims for oat and barley, in US (FDA) and Canada, and oat-derived product (bran, flours ect.) claims in UK, Finland and Sweden. Moreover, many fiber-fortified foods have government-backed FOSHU status for their health benefits in Japan[9,10].

Consumption of soluble fiber has been shown to lower LDL-cholesterol levels through a series of processes that alter cholesterol and glucose metabolism. The mechanism of action is thought to involve increasing fecal bile acid excretion and interference with bile acid re-absorption. The fermentation of fiber in the colon by intestinal flora leads to production of short-chain fatty acids (SCFA: acetate, propionate, butyrate) and gases. The SCFA not only provide fuel for the colonocytes, but their production is related to lower serum cholesterol and decreased risk of colon cancer (particularly in the case of butyrate production). Undigested fibers also increase fecal wet weight and speed intestinal transit. Eating insoluble fiber has been also shown to reduce the risk of developing constipation, colitis, and even hemorrhoids. High fiber diets, both soluble and insoluble components, are shown by many clinical data to effectively control (moderate) the post-prandrial glucose and insulin blood levels, becoming suitable for both types of diabetics, I and II. Indeed, soluble dietary fiber, such as oat β-glucan, psyllium, and guar gum have been recommended for improvement of postprandial insulin and glucose metabolism, in addition to antihyperlipidemic effects. These viscous polysaccharides in a composite food matrix can slow down the rate of carbohydrate digestion and absorption (low Glycemic Index products); inverse relationships have been shown between postprandial blood glucose and insulin responses and the viscosity of the liquid products consumed[10]. For soluble oat and barley β-glucans, an efficacious dose of 3 g/day has been recommended by FDA for reduction of CHD risk.

The great challenge to the food industry in formulating fiber-enriched products is to accomplish this goal without sacrificing the organoleptic appeal (color, flavor, texture, mouthfeel). These objectives can be achieved by understanding the structural and physicochemical basics of fiber functionality (from both technological and physiological viewpoint). New forms of dietary fiber, e.g. 'resistant' starches, offer unique opportunities in

this respect, with a broad spectrum of bioactivities and texture modulating properties. The bland flavor, white color, low hydroscopicity, low water binding capacity and the thermal stability of this group of fibers enable their utilization as low-calorie ingredients that are easily incorporated in numerous product recipes, without altering the basic hedonic properties of the food matrix[10-12].

The area of *probiotics* is one of the most sophisticated approaches to customizing health benefits of FF; i.e. health-promoting bacteria (such as those found in milk, yoghurt and other fermented products) that may favorably alter the floral composition of the gut by competition[13]. This will not only improve digestion, but also provides protection against gastrointestinal infections by boosting immunity, controlling antagonistically pathogenic organisms in the gut, and improving the bioavailability of nutrients. Conversely, *prebiotics* (indigestible non-viable food components) alter the bacterial composition of the gut by becoming selective fermentation substrates for the beneficial bacteria in the lower part of the GI tract. Positive health benefits of probiotic-prebiotic mixtures in food products include reduction in serum cholesterol, improvement of lactose metabolism - treatment of diarrhea, protection from gastrointestinal diseases, specific immune-enhancing effects, etc. Although the initial thinking has been that the presence of one type of bacteria rather than another in the gut is adequate to produce such effects, more recent evidence suggests that secondary fermentation products (e.g. SCFA, bioactive peptides) may also contribute to the health benefits of these systems[2,7,13]. Several strains of *Lactobacilus* and *Bifidobacterium* have been employed to generate functional products with live cultures; some of these products contain a mixture of probiotic strains. For yoghurt to be considered as a probiotic product, *L. acidophilus, Bifidobacterium* and *L. casei* are incorporated as dietary adjuncts; e.g. products such as Yakult contain the *L. acidophilus* Shirota strain. However, the normal practice in making probiotic fermented dairy products with regular starter cultures, *Str. thermophilus* and *L. delbrueckii* ssp. *bulgaricus*, is to use them with one or more species of probiotic bacteria. Probiotics in food products is showing the greatest growth potential over the next five years; the current US market alone for probiotic-infused yoghurt drinks is pegged at $ 12 billion and expected to reach $ 15 billion in 2010.

TECHNOLOGY INNOVATION FOR NEW NUTRITIONAL CONCEPTS

The efficacy of FF is based on bioactive compounds, which may be contained naturally in the product or require specific formulation and application of appropriate technologies to optimize the desired beneficial properties, to enhance stability during processing and storage, and to improve delivery at the target site(s) in the body[14]. Emerging technologies such as microencapsulation, new packaging strategies etc. might offer solutions to many technical challenges in formulating with bioactives in the FF arena. For example, microencapsulation of ω-3 lipids with a nanoscale level coating to protect them from light, oxygen, temperature and acidity offers an effective delivery strategy to supply a complete daily requirement of these lipids in a single serving without any compromise in taste or aroma (avoiding the development of off-flavor oxidation products and fishy taste). The same technology can be applied to enhance the delivery of viable cells (probiotics) and facilitate their controlled release in the GI tract. Co-entrapment (co-encapsulation) of mixtures of bioactives to protect them from interactions with the food matrix or oxygen during storage, and enhance their functionality on ingestion is also feasible in this context. Bioactive peptides, such as bacteriocins, are good candidates for co-encapsulation with probiotic bacteria to complement their antimicrobial activities, especially if the health target is protection against diarrhea[15]. Nanoparticles, due to their subcellular size, offer promising means of improving the bioavailability of nutraceuticals, especially poorly soluble molecules such as functional lipids (carotenoids, ω-3 fatty acids, phytosterols), natural antioxidants, and numerous other compounds that exhibit physiological functionality[16]. Advances in active packaging also offer possibilities to extent shelf-life, improve efficacy and allow for controlled release rates of the carried antimicrobials or other bioactive compounds. In summary, co-encapsulation not only offers the possibility of introducing multiple bioactives, but it also enables the creative selection of ingredients that will act synergistically in the gut environment.

CONCLUSIONS

Functional foods are a new category of products that attract the attention of consumers, food manufacturers and regulatory authorities. Several of these products with well-proven efficacy (e.g. those containing phytosterols, fibers, antioxidants, probiotic cultures and other nutraceuticals) have gained popularity on the global market and offered continued growth, product diversification (added-value), and sustainability to the food manufacturing sector. For many bioactives, there is sufficient scientific evidence to link their consumption with certain health benefits. In contrast, for other ingredients there is still a need for more research and further clinical evidence to prove their physiological functionality. However, health claims of any type must be based on science and not science fiction. Greater fundamental understanding at a molecular level is also required for the newly emerging technologies on the development of effective delivery systems involving nanoparticles to broaden the applicability of these approaches and to ensure safety and compliance with regulatory issues.

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Primljeno: 11.4.2008. Prihvaćeno: 15.4.2008.