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Received: October 2018 – Accepted: February 2019

Functional foods

Keywords: functional foods, dietary supplements, prebiotics, phytochemicals, ADI value, LDL and HDL cholesterol, functional food production technology, food safety, microrisk, fortification, restoration, enrichment, standardization, substitution, vitamins, microelements, micronutrients, deficiency diseases, polyphenols, flavonoids, essential fatty acids, polyunsaturated fatty acids (PUFAs), conjugated linoleic acids (CLAs).

SUMMARY

Functional foods are products that contain the ingredients in sufficient quantities, but have a greater impact on vital functions than traditional foods, contribute to the prevention of diseases, have a health protection effect, and thus overall they have a particularly beneficial effect on the human body. The key question in the production of functional foods is to determine what additional component should be added to the product so that the desired functional effect, especially supportive of life processes, can develop in the human body. Before being released for public consumption, the physiological effects of functional foods, the good manufacturing practice of the product, consumer needs, food safety related to functional foods and legal regulation should be clarified. The production of functional foods is a relatively new area where technology development and consumer acceptance are still taking place today, so producers and consumers can even co-manage processes that will be incorporated into traditional food production practices in a few years' time.

In the first half of our article, the basic concepts of functional foods are discussed, then the characteristic properties of some functional foods produced by supplementing foods with chemical substances are described. Due to the length limitations of the article, discussion of products manufactured with microbiological live cultures is planned for a later time.

Introduction

Functional foods are products that contain sufficient, generally above average, quantities of constituents that have an especially beneficial effect on one or more vital functions, contribute to mental well-being, and their regular consumption can reduce the risk of illnesses caused by malnutrition. In addition to having the energy content and nutritional value of traditional foods, they have a health protection effect **[1]**.

In the scientific literature, foods that contain less than usual amounts of a certain ingredient are also called *functional*. Examples include reduced fat, carbohydrate or protein products.

Among functional foods, foods that contain drug active ingredients in amounts close to pharmaceutical formulations are called nutraceuticals. It is important to note that, according to the current regulations in the European Union, nutraceuticals are considered dietary supplements. The term *medicinal product* cannot be used **[2]**.

The *prebiotics* of *prebiotic* products, also considered functional foods, facilitate the growth of microorganisms that are beneficial to humans in the gastrointestinal tract, while at the same time reducing the number of harmful microorganisms, thereby facilitating the formation of a microbiome of more favorable composition in the gastrointestinal tract. *Probiotics* are cultures that contain living microorganisms. In the case of a certain group of probiotic foods, the culture itself is the raw material (carrier) of the food, while in other cases the active culture is added to the non-probiotic product subsequently **[3, 4]**.

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The necessity of consuming functional foods – deficiency diseases

Among minerals, the deficiency of zinc, selenium, iron, iodine and calcium, while in the case of vitamins, that of vitamin A and D, as well as of folic acid is most common, but in corn-consuming societies, niacin deficiency is quite frequent as well. Thiamine deficiency is characteristic of rice-consuming populations, while scurvy due to vitamin C deficiency is typical in populations that consume small amounts of fresh fruits and vegetables **[5]**. Today, two billion people suffer from iron deficiency, 1.9 billion from iodine deficiency. Due to the lack of vitamin A, 250 million children of school age are at risk of blindness **[6]**. Deficiency diseases are most prevalent where the diet is based on cereals and legumes, and not enough food of animal origin is consumed, especially meat, as well as fresh fruits and vegetables. The low selenium and iodine content of foods, which can be observed in foods of both plant and animal origin, can be explained by the low concentration of these elements in the soil **[83]**. In the following, the importance of consuming functional foods will be illustrated with a brief summary of the characteristics of some deficiency diseases that occur because of shortcomings in the diet, without being exhaustive.

Iron deficiency and its consequences

Roughly 30% of the world's population has iron deficiency (ID). One billion of them suffer from iron deficiency anemia (IDA), while the other billion people have iron deficiency without anemia. The latter is called latent iron deficiency (LID) or iron-deficient erythro-poiesis (IDE) in clinical terminology. In our body, 95% of the total iron is bound to hemoglobin and myoglobin. Significant amounts of iron are also present in the cytochrome and NADH dehydrogenase enzymes **[8]**.

Some iron-containing enzymes are tools of the immune defense; iron deficiency leads to fatigue and weakness, the resistance to infections is reduced, work capacity is reduced, mortality is increased, babies are born with lower weight, the learning and perception ability of children is reduced. Significant sources of iron include meat and meat products, because they contain iron in a hem-bound form. The absorption of iron bound to hem practically not affected by food ingredients. However, the absorption of iron not bound to hem depends significantly on the oxidation state of iron and on food ingredients **[9]**. To reduce iron deficiency, flour, rice, fish and soy sauce, as well as corn supplemented with iron have been marketed, and also milk and dairy products with an increased iron content **[10]**.

Iodine deficiency and its consequences

Iodine deficiency due to shortcomings in the diet occurs almost all over the world. In Europe, roughly 60% of children had suffered from iodine deficiency until the use of iodinated salt became common practice. Iodine is an essential component of the hormones produced by the thyroid, which are necessary for the development of nerve tissue and the brain during intrauterine life and the postpartum period. Reduced iodine intake results in functional physiological disorders, which are generally referred to as iodine deficiency disorders. The condition due to a low iodine intake is exacerbated by the lack of selenium and iron, because both microelements are required for the synthesis of thyroid hormones. An obvious solution for iodine deficiency is the consumption of iodized salt. In addition to iodized salt, iodized water, various iodized sauces and iodized wheat flour can also serve as suitable sources of iodine for humans **[11]**.

Vitamin A deficiency and its consequences

Among other things, vitamin A deficiency is responsible for the development of childhood blindness **[12]**. About 500,000 children become blind every year as a result of vitamin A deficiency, and 50% of them die within a year. Vitamin A is required for the development of rhodopsin, also called visual purple, the development of the visual system, retinoic acid is required in the bone marrow, for the development of myeloid cells that play an essential role in the functioning of the immune system, for growth, development and reproduction. In the case of a higher vitamin A intake, the excess amount is stored in the liver, from which it is released during a vitamin deficient diet, and becomes available to the metabolism of the body **[13]**. The most important sources of vitamin A are milk and dairy products, as well as liver. The vitamin A content of cereals and legumes is low, therefore, vitamin A deficiency is common in individuals whose diet is based on cereals and legumes. To satisfy vitamin A requirements, margarine and other vegetable oils and cooking oils supplemented with vitamin A are commonly used **[14]**.

Zinc deficiency and its consequences

Zinc is required for the functioning of about 100 enzymes involved in metabolism, growth, the development of the immune system, reproduction and the development of the nervous system. Zinc deficiency occurs primarily in the case of a diet based on cereals and legumes, coupled with low meat, milk and dairy product consumption. Nevertheless, supplementation of foods with zinc has not become a common practice **[15]**.

Calcium deficiency and its consequences

Calcium deficiency occurs in populations worldwide where there is no tradition of consuming milk and dairy products. The human body can regulate its own calcium content effectively. In the case of a deficiency, the required amount is replenished by the body from the bones. In children, a deficient supply of calcium and vitamin D does not allow the development of strong bones, which can lead to osteoporosis later in life **[16]**. Depending on age, the daily calcium requirement of an adult is 1000 to 1200 mg, most of which can be covered by the consumption of milk and dairy products. Where milk and dairy product consumption is minimal, calcium deficiency can be expected **[17]**.

Calcium absorption is closely related to optimal vitamin D intake, because where the vitamin D content of foods is low, calcium absorption disorders are common. Foods enriched with calcium and vitamin D help the young body reach the genetically determined maximum calcium content in the bones, which later reduces the risk of osteoporosis **[18]**.

Folic acid deficiency and its consequences

Folic acid deficiency can occur in cases when foods made from refined ingredients are consumed or leafy vegetables are not consumed in sufficient quantities. Folates, as part of the vitamin B complex, contribute to the synthesis of coenzyme A in the body. In their absence, many biochemical processes can be inhibited in the human body **[19]**. Inadequate folic acid supply or problems in the folic acid metabolism can lead to an increase in the number of babies born with split spine, megaloblastic anemia, neurological degeneration, cancer and cardiovascular problems. Addition of folic acid to foods, especially flour, has significantly contributed to the reduction of diseases previously attributed to folic acid deficiency **[19]**.

General characterization of functional foods

The highly beneficial physiological effects and suitability of functional foods can be judged by the following criteria, among others **[20]**:

- Chemical and microbiological properties of added functional ingredients;
- Quantity of ingredients with a functional effect;
- Actual physiological effect of functional ingredients;
- Manufacturing technological steps of the products, critical points in the production process;
- Sensory properties of the foods enriched with functional ingredients;
- Food safety characteristics of the products (shelf life, risk and danger of overdose of ingredients).

Some common functional ingredients **[21], [22]**:

- Dietary fibers (water-insoluble and water-soluble dietary fibers);
- Natural compounds (phytochemicals), antioxidants, which may sometimes be effective against the development of cancer (polyphenols, anthocyanins, low molecular weight organic compounds, vitamins);
- Microelements linked to the prosthetic group of metabolic enzymes;
- Polyunsaturated fatty acids (PUFAs), which are important components of the membranes of the nervous system, having a scavanger effect;
- Special proteins that serve to increase the nitrogen supply and to strengthen the skeletal system of individuals consuming the functional foods (e.g., bakery products can be enriched with milk, whey or casein, but enrichment with peptides is also used);
- Microbiological live cultures (with lactic acid bacteria, kefir fungi, etc.);
- Vitamins (water-soluble or fat-soluble vitamins).

There are several health protection components known that are produced from colostrum or milk, and are used to prevent or cure certain diseases **[18]**.

Certain oligosaccharides may act as prebiotics, because they have a beneficial effect on the development of microorganisms living in the intestinal tract **[23, 24]**. Functional foods are often supplemented with vitamins. However, especially in the case fat-soluble vitamins, an overdose can be dangerous, therefore, when determining the dosage, knowing the consumption habits of the given food, only the amount of vitamin corresponding to the ADI value (ADI - Acceptable Daily Intake) should be added to the product in the technology. Natural sweeteners are often used in functional food products to replace energy-rich sugars (energy-depleted products) **[25]**.

Physiological effects of functional foods

By consuming functional foods, inhibition of oxidative (free radical) damage to the human body **[26]**, an antimutagenic effect **[27]**, an anticarcinogenic effect **[28, 29, 30]**, a dietary fiber effect **[31, 24]**, an immunomodulatory effect **[18, 32]**, an estrogenic effect **[33]**, an antioxidant effect **[34]**, an antihypertensive effect **[35, 26]**, an antiinflammatory effect on the pancreas **[36]** and an antiallergenic effects **[37]** can be expected. To prevent heart and cardiovascular diseases, “heart-friendly” foods have been developed, which lower LDL cholesterol (LDL – Low Density Lipoprotein) levels, for example **[38, 39]**.

Safety of functional foods, their legal status

In the European Union, functional foods are subject to the same legal framework as traditional foods **[40]**. At the same time, the regulation regarding the details of the food economy is not yet fully uniform. Member

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states also apply their own regulations, but the health claims that can be included on the food label are regulated uniformly in the Union **[41].** Standardization regarding functional foods is currently under way. In Hungarian supervision, the National Institute of Pharmacy and Nutrition (OGYÉI) plays a central role. Currently, OGYÉI performs professional coordination and expert tasks in the field of dietary supplements and formulas. The Hungarian legal system is governed by decree 37/2004 of the former Ministry of Health, Social and Family Affairs **[42]**. Supervision of the food chain (composition, safety, documentation, labeling, manufacture, distribution, etc.) is within the competence of **NÉBIH** and the county government offices.

Food quality is the sum of those properties of food that make it suitable for meeting the requirements prescribed by the law and the demands of the customers. It is a basic requirement that the consumption of the food is not accompanied by a risk that exceeds acceptable levels. Accordingly, foods whose long-term consumption does not present a detectable health risk can be considered safe. At the same time, the existence of foods that can be consumed *completely risk-free* is physically inconceivable, but the harm caused by foods intended for public consumption must not be greater than four times the *microrisk* level accepted by society, also suppported by laws. A microrisk represents a damaging effect that causes an additional death in a population of one million in case of a lifetime consumption **[43]**.

Examination of the effect of functional foods of different compositions, the food safety obligation of the products is always the responsibility of the manufacturer and/or the distributor **[44]**. Newly developed products are generally tested to determine what the risks of an overdose are, whether the added functional ingredient exerts the desired nutritional physiology effect, whether there is a risk that the ingredients and the components of normal foods are toxic, and what the likelihood is of unwanted cross-reactions.

Manufacturing technology and safety of functional foods

Production of functional foods by food supplementation

Supplementing foods with various micronutrients goes back to several centuries. In the old days, to cure iron deficiency, iron nails were pushed into an apple, for a greater calcium intake corn was soaked in lime water, and salt was supplemented with iodine to prevent goiter **[45]**. Margarine was supplemented with vitamin A to try to eliminate vitamin A deficiency, wheat flour was supplemented with thiamine, niacin and iron **[46]**, and calcium supplemented flour was also marketed **[47]**.

Increasing the amount of functional ingredients in foods

The addition of functional ingredients in accordance with good manufacturing practice should not alter the sensory properties of the food.

The research team at the University of Debrecen added the amino acid lysine to wheat flour to treat the essential amino acid deficiency resulting from nutritional deficiencies. The amino acid supplementation increased the nutritional biology value of the product, and the sensory properties of products baked from flour containing no more than 1.5% added lysine did not change **[48]**.

In addition to well-known supplements (iodized salt, supplementation of margarine with vitamins A and D, or the restoration or fortification of flour), methods have been developed for the prevention of rickets by increasing the vitamin D content of milk. Niacin, thiamine and folic acid were added to flour to prevent beriberi and pellagra, and iron was added to wheat flour to prevent anemia. In developing countries, the most important staple foods are supplemented primarily with vitamins and minerals (micronutrients). Foods made from potatoes, cereals and fruits are supplemented with micronutrients, microelements and vitamin C. Of micronutrients, the effect of folic acid supplementation on human health has been studied most often. It was found that a folic acid-deficient diet could increase the proportion of babies born with a split spine, so foods made from cereals were supplemented with folic acid in the United States. The consumption of such foods with an increased folic acid content has been recommended to pregnant mothers **[49]**.

Folic acid supplementation has lead to vitamin B_{12} deficiency in elderly people. It follows that supplementation with a micronutrient may occasionally cause the deficiency of another functional ingredient. Thus, in addition to the beneficial effect, supplementation may also have harmful consequences **[50]**.

Replacing certain components of foods

It is difficult to replace whole milk and dairy products with other, low-fat food ingredients in products intended for consumers who require a low-fat diet. The reason for this is that whole milk contains significant amounts of fat-soluble vitamins, and the removal of fat also removes considerable amounts of the vitamins in the technology. The situation is similar in the case of meat replacement with a plant-based raw material, such as soy. In both cases, to maintain the amount of fat-soluble vitamins, vitamin, mineral and essential amino acid supplements should be used **[51]**. When margarines replacing fat have gained acceptance, they were supplemented with vitamins A and D, as well as carotene.

Enrichment and supplementation of the functional components of foods

Enrichment results in a special product that contains significant amounts of one or more food components and is targeted at a narrow group of consumer populations. The most well-known enriched products are multivitamins, vitamins mixed with minerals, and capsules containing various amounts of vitamin C. These supplements are consumed for safe nutrition and for therapeutic purposes. In some cases, consumers also expect a pronounced healing effect from these products. In the case of elderly people, to prevent osteoporosis, dietary supplements containing mainly calcium and vitamin D should be used.

Enrichment and supplementation of foods with vitamins

Vitamins are among the less stable food components. Stability varies with the type of vitamin; there are more stable vitamins (niacin) and there are less stable ones (vitamin B_{12}). The stability of vitamins is mainly influenced by the temperature, humidity, oxygen, light, pH, the presence of oxidation and reduction components, the presence of heavy metal ions (copper, iron), the amount of sulfur dioxide, the presence of other vitamins, or the combination of the above effects. The most important of these factors are temperature, humidity, oxygen, pH and light. Particularly high levels of vitamin loss can be expected where a significant heat treatment is applied. Vitamin content may also change from time to time **[52]**. Adhering to the declared vitamin content is difficult, because vitamins decompose with different dynamics. On the product label, their vitamin content should be indicated with this in mind: the vitamin content should not exceed the relevant ADI value on the first day out of the plant, but the vitamin content necessary for functionality should still exist on the date of expiration **[53, 54]**.

Vitamins can also react with each other in the finished products, which can result in decomposition. Research on liquid multivitamin preparations has shown about 13 vitamins that their interactions accelerate the decomposition of other vitamins. The most important of these were ascorbic acid, thiamine, riboflavin and cyanocobalamin. Ascorbic acid increases the instability of folic acid and cyanocobalamin, thiamine increases the instability of folic acid and cyanocobalamin, while riboflavin increases the instability of thiamine, folic acid and ascorbic acid. Vitamins may also reduce or increase the solubility of other vitamins **[55]**. The vitamin content of foods decreases as a result of irradiation, the extent of which is clearly related to the intensity of the irradiation. Exposure to an irradiation of 3 to 10 kGy in the presence of air already may result in vitamin loss, which increases further during storage. Of fat-soluble vitamins, vitamins A, E and K are sensitive to irradiation, while of water-soluble vitamins, thiamine is the most sensitive, niacin, riboflavin and vitamin D are not sensitive to it **[56]**.

Polyphenols to develop antioxidant properties of foods

Polyphenols, also known as flavonoids, are the secondary metabolic products of plants, of which more than six thousand have been identified to date **[57]**. The intense antioxidant properties of these molecules are provided by the hydroxyl groups attached to the phenolic ring. Based on their structure, flavonoids can be divided into six groups: flavonols, flavones, catechins, flavonones, anthocyanidins and isoflavones. These compounds, as antioxidants, are capable of modifying the activity of key enzymes, they possess vasodilatory, antitumor, antiinflammatory and immune-enhancing effects. The most important flavonoid sources are fruit juices, coffee, tea, red wine, onions, apples and berries, black currant and blueberries. The main flavonoids present in foods are catechin and catechin gallates, as well as quercetin and campferol, and their glycosides **[84]**.

Food supplementation with carotenoids

Carotenoids are a large group of plant pigments. Their color may vary from yellow to red in nature. Foods contain approximately 50 to 60 different carotenoids. β-Carotene is the provitamin of vitamin A, from which the body can synthesize two molecules of vitamin A with the help of the carotenase enzyme. Food supplementation with β-carotene has a long history, for example, fruit juices have been supplemented with β-carotene for a long time, so previously carotenoids were mostly used as food colorants. Of the many carotenoids, the most important are β-carotene, α-carotene, β-cryptoxanthin, lutein, which is not a provitamin of vitamin A, zeaxanthin and lycopene **[58]**.

The health effect of carotenoids is attributed to their outstanding antioxidant effect. β-Carotene is converted into two molecules of vitamin A, lutein and zeaxanthin contribute to the healthy functioning of the eye, and lycopene can help in the prevention of prostate cancer. The amount of added carotene is primarily determined by the desired color and its health efficiency. Nowadays, β-carotene and lycopene are widely used in the food industry for coloring foods. β-Carotene is used in large quantities for coloring margarines, butter, cheese, yogurt and ice cream, it is also used in bakery products, soups, sauces, salad dressings and desserts, and is used in large quantities in the production of multivitamin drinks **[59]**.

Food supplementation with oils containing essential fatty acids

Some lipids have been shown to have health effects and occasionally they are essential for the human body. They include steroids that lower LDL cholesterol levels (their chemical structure showing a high degree of similarity to the structure of cholesterol), and certain fatty acids that possess antiinflammatory effects. Plant steroids are very similar to cholesterol in their chemical structure. Their most important representatives are sitosterol, campesterol and stigmasterol. Plant stanols are saturated plant sterols that contain no double bonds in the steroid rings. Plant steroids have no effect on HDL cholesterol levels, but as they improve the LDL/HDL ratio, they have a health effect **[60]**.

Polyunsaturated fatty acids

The term polyunsaturated fatty acid (PUFA) is used for all fatty acids that contain at least two unsaturated bonds. Among them, linoleic acid (C18:2) and linolenic acid (C18:3) are essential for humans, because our bodies cannot produce them, and at the same time they are indispensable for the construction of the nervous system and cell membranes in general. From both fatty acids, the body produces hormone-like eicosanoid compounds, among other things, that modulate the cardiovascular, respiratory and immune systems, as well as reproductive functions, and play a key role in preventing inflammation **[61]**. The synthesis of eicosanoids in the human body depends on the type of available fatty acids, therefore, the ω-3/ω-6 ratio of the foods consumed determines the amount of eicosanoids that can be produced from them **[62]**. Some authors believe that the 4:1 ω-3/ω-6 ratio is optimal for the human body, but ratios of 7:1 and 14:1 have been measured in several countries, which are far from optimal **[63]**.

Sources of polyunsaturated fatty acids

The optimal raw materials for supplementing with PUFA are various vegetable oils, such as primrose oil and linseed oil, characterized by a typical ω-3/ω-6 ratio. Fish oils contain particularly high amounts of eicosapentaenoic acid (EPA – C20:5 n-3) and docosahexaenoic acid (DHA – C22:6 n-3). In general, vegetable oils contain many n-3 PUFA fatty acids in the form of linolenic acid **[64]**. Since it is the same enzyme system that converts linoleic acid and linolenic acid into longer chain unsaturated fatty acids, the two fatty acids act as competitive inhibitors of each other, therefore, only a part of linolenic acid is capable of being converted into EPA and arachidonic acid **[65]**. The main sources of EPA and DHA are fish oils, which are the “byproducts” of fish meal production. The fatty acid composition of fish oil depends on the composition of the feed consumed by the fish, so there may be significant differences in the fatty acid composition of fish oils coming from different locations. The EPA content of fish oils ranges from 5 to 18%, while their DHA content is between 6 and 13%. Marine microalgae appear to be the best sources of n-3 fatty acids, because they are able to accumulate long chain n-3 fatty acids in their bodies **[66]**.

Conjugated linoleic acids

Conjugated linoleic acids (CLA) also contain two double bonds, but they are in conjugated positions in the molecule. CLA reduces fat storage after meals, reduces the total amount of fat cells, and increases the involvement of fats in energy-producing processes **[67]**. CLA compounds also have an immunomodulatory effect, they influence the immune response of the cells to vaccines, the body’s cytokine levels, and thus may play a role in the treatment of inflammations. Of the many CLA isomers, the *cis-9,trans-11* and *trans-10,cis-12* isomers possess significant biological activities. Commercially available CLA products are made from safflower oil, containing both isomers in 50% ratios **[7]**.

Technological aspects of lipids

In the production of CLA, it is a basic requirement that the isomers with biological activity are produced in the highest concentrations. Products that contain large amounts of unsaturated fatty acids are susceptible to oxidation, therefore, antioxidants, such as tocopherol mixtures, ascorbyl palmitate, rosemary extract or citric acid are often used in these products. The basic compounds of lipid oxidation are fatty acids containing double bonds. The more double bonds there are in a molecule, the more susceptible it will be to oxidation, thus DHA is five times more susceptible to oxidation than linoleic acid. Autooxidation is started by initiators, resulting in the formation of free radicals localized on carbon atoms from the unsaturated fatty acids. After further decomposition, they form volatile or non-volatile secondary products **[68]**.

Volatile components include aldehydes, ketones, alcohols and certain hydrocarbons, which are responsible for the development of rancid odor and taste. Photooxidation is a non-radical reaction that leads to the formation of hydroperoxides and volatile components, such as those formed in the radical reactions. Chlorophyll, riboflavin and hem proteins are photosensitizing compounds in foods. In some cases, lipid oxidation can be prevented by the administration of antioxidants. Primary antioxidants are also called free radical scavengers, because they stop radical reactions by the neutralization of free radicals. Artificially produced antioxidants are phenolic compounds, such as BHA (butylhydroxyanisole), BHT (butylhydroxytoluene) and propyl gallate, while tocopherols and plant polyphenols are natural antioxidants **[2, 69]**.

Due to the chemical properties described above, the sensitivity of the compounds must be taken into account in the manufacturing technology. Heat treatment parameters (temperature, holding time) of dietary supplements have to be adjusted carefully. Occasionally, the oxygen in the air should be excluded from the technological process.

Food supplementation with lipids that possess biological activity

Long chain PUFAs and CLAs are usually added to foods in an esterified form after deodorization. It is always advisable to add an emulsifier to oils, which increases dispersion, provides stability to the food, and prevents the separation of the different phases. Generally, a homogenization step is also included in the manufacturing process to reach the necessary degree of dispersity and stability **[68]**. To facilitate the addition of functional lipid components, various spray-dried products have been prepared which can be mixed easily and homogeneously in aqueous media. Sterols in their original state are difficult to disperse uniformly in an aqueous medium, because these compounds are highly hydrophobic and, after simple mixing, they separate immediately from the aqueous medium **[69]**.

Today, sterol-supplemented drinks and cereals are the most popular among the consumers in the United States. Also popular are small volume milk drinks, 100 grams of which contain 2 to 3 g of plant sterols. Also readily consumed are yogurt, milk, milk powder and spreadable cheeses supplemented with plant sterols **[70]**. In recent years, dietary supplements for infants and elderly people have been manufactured and marketed with PUFAs, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). In addition to milk and dairy products, numerous so-called omega breads are available commercially, in which the PUFA concentration is 80 mg/100 g on average **[71]**.

Flavonoids as functional food components

Flavonoids are the secondary metabolic products of plant metabolism, and they are found primarily in the skin, seed and stalk of the fruits. As pigments, they play a role in the protection against UV light, microorganisms and other plant pests, in the regulation of enzyme reactions, and also have a signaling function for nitrogen-binding bacteria. In foods they are coloring agents, flavor components and antioxidants. In their basic skeleton, the aglycone is attached to a sugar molecule, so flavonoids are actually glycosides. Flavonoids are 1,3-diphenylpropane, isoflavonoids are 1,2-diphenylpropane and neoflavonoids are 1,1-diphenylpropane derivatives, and this group also includes anthocyanidine, cyanidine, anthocyanin and cyanin **[72]**.

Characteristic representatives of the flavonol group are catechins, of proanthocyanidins are oligomeric catechins, of flavones are quercetin and campferol, of biflavones are amentoflavone and bilobetin, of flavonones are hesperidine and naringin, of flavononols is taxifoline, of anthocyanins are cyanidine, delphinidin, malvidin and petunidin, of flavonolignans is silmarine, and of isoflavones are genistein and daidzein **[73]**.

In 2001, the flavonoid consumption in Hungary was 18.8 mg/person/day (0.5-309.7 mg) for adults and 19.5 mg/person/day (0-179.3 mg) for children, while the recommended intake is 1,000 mg/person/day. The above data show that in Hungary the consumption of vegetables and fruits is far below the desired level **[1]**.

Absorption and metabolism of flavonoids

The absorption of flavonoids depends on their chemical structure, the size of the molecule, the degree of polymerization, glycosidation and the solubility of the compounds. Flavonoid-type molecules are generally poorly absorbed, only 0.2 to 0.5 percent of the total amount consumed is utilized by the body **[74]**. These molecules are transformed by decarboxylation, demethylation, the saturation of the double bonds, and then the aglycons are absorbed through the small intestine. Glycosides must be hydrolyzed prior to absorption, but the β-glucosidase enzyme is absent in humans, so glycosides are hydrolyzed by the microbiome of the colon, then the metabolites reach the liver through the bloodstream where they are methylated and sulfonated, then they reach the kidneys with the blood and excreted in the urine **[75]**.

The most important biochemical properties of flavonoids are the antioxidant effect by capturing free radicals, the antiinflammatory effect, the antiasthma and antiallergic effect, modification of enzyme activation, usually their inhibition, the antiviral and antibacterial effect, estrogen activity, the effect influencing mutagenesis and carcinogenesis, the hepatoprotective effect, and the effect on the functioning of the blood vessel system **[76]**.

Based on our current knowledge, malignant tumors cannot be prevented by any diet or the consumption of any dietary supplement, but the risk of these diseases is lower in those populations that consume large amounts of fruits and vegetables **[77]**.

In Mediterranean countries, the number of people suffering from cardiovascular disease is smaller, which is believed to be due to the flavonoid content of the red wine consumed (French paradox: despite the high fat French diet, the number of cardiovascular diseases in France is lower than in other countries that consume less fat on average.) **[78]**. Flavonoids reduce the fibrinogen concentration and increase the plasminogen concentration, increase the levels of protective HDL (High Density Lipoprotein), while reducing the levels of harmful LDL. Red wine can be considered a “functional food”, because flavonoids are absorbed to a higher degree from an aqueous, alcoholic liquid than they do from other foods **[79]**. Nevertheless, it is likely that the lower incidence of cardiovascular diseases in France is not only the result of red wine consumption, but also of lifestyle and genetic differences **[80]**.

Flavonoids have been found to restore bone physiological metabolism in the case of osteoporosis and osteogenesis disorders, to increase insulin production in diabetic patients, to promote estrogen hormone production in the case of gynecological problems, to play a role in the prevention of Alzheimer's disease, and to promote the absorption of drugs **[81]**. Quercetin inhibits the functioning of the xanthin oxidase enzyme required for uric acid formation, thereby effectively reducing the risk of developing gout **[82]**.

Discussion

In connection with functional foods, we intended to write about a new area of food production whose technology is still being developed, made known and accepted by customers these days, that is why producers and consumers together manage the processes that will be part of traditional food production. Naturally, in this brief communication we could only touch on the most important knowledge regarding functional foods, including definitions describing the conditions under which a food can be considered functional, the physiological effects of functional foods, the basic conditions of the production of functional foods, and consumer requirements for functional foods. We also briefly touched upon the issues of food safety and legal regulation.

In the second half of our article, we have written about increasing the amount of functional components of food, about substitution, enrichment and supplementation. Within this part, we discussed in more detail the supplementation of foods with vitamins and minerals, and their enrichment with polyphenols and essential and health-enhancing fatty acids. The length limitations of our article did not allow us to discuss the bioactive components of milk, their extraction, enrichment and production, bioactive proteins, lipids and carbohydrates, prebiotics, probiotics and synbiotics, as well as functional foods or foods that can be made functional such as meat, eggs, soy, various cereals, fruits and vegetables, nutritional sprouts and red wine. According to our plans, these will be covered in a literature review at a later date.

Acknowledgement

The publication is supported by the EFOP-3.6.3-VEKOP-16-2017-00008 project. The project is co-financed by the European Union and the European Social Fund.

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