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Nutraceuticals in food and pharmacy. A Review

Nutraceutyki w żywności i farmacji. Praca przeglądowa

Summary. The increase in consumer awareness about food and health has led to an increase in the demand for food containing biologically active compounds, especially antioxidants, which can help the human body fight the oxidative stress. Many unconventional or new sources of antioxidants have been discovered, which is a priority not only for food, but also for the pharmaceutical industry. It has been shown that not only raw materials, but also waste from fruit and vegetable processing contains valuable molecules, such as: proteins, essential amino acids, antioxidants, dietary fibers, natural pigments, or aromatic compounds, that can be extracted, purified and modernized in food products or pharmaceuticals with added value. This is the basis of huge potential of not only plant and biotechnology raw materials, but also food waste for the use as a source of antioxidants.

Key words: bioactive compounds, bioavailability, antioxidants, natural dyes, use of food waste, functional ingredients of food, health benefits, marketing, health

INTRODUCTION

It is estimated that approximately 815 million people in the world suffer from hunger and malnutrition; 1/12 of people in the world suffer from malnutrition, including 160 million children under 5-years-old; approximately 183 million children weigh less than they should at their age; every 3.6 seconds, someone dies of hunger, but every minute 57 children die of hunger, and 55% of all children in the world suffer from malnutrition [WHO Report 2018, FAOSTAT 2018]. There are more and more people also suffering

from the shortage of food. More and more products are gaining importance at the interface between food and medicines. Consumers are now looking for complementary or alternative, beneficial products and are therefore currently using nutraceuticals. They are increasingly using natural dietary supplements and other forms of nutraceuticals as part of massive growth to gain physiological benefits or protect against disease [Rehniquist 2003, ENA 2017, FDA 2018].

Dietary supplements, in turn, are intended to provide the body through the gastrointestinal tract with such substances that are desirable to the body, but are not, or are not properly supplied by food or other routes of delivery (e.g. through the skin). The question “which substances are currently desirable?”, especially for the body, may change [ENA 2017]. The development of better proven products will help increase consumer confidence in nutraceutical and functional food products around the world. The modern man eats about one ton of food a year. In this mass, there are about 5–7 kg of various chemical substances as preservatives and pigments, other technological additives, the nutritional value of which is zero [Blecha and Wawer 2011, <http://www.nutrition.org.uk>]. Hence, various sources of food are sought in the world. This paper reviews the latest scientific knowledge about the bioavailability and biological activity of nutraceuticals.

DEFINITIONS AND OPERATION MECHANISM

We are increasingly looking for new substances that can improve biological function or make us more efficient and healthier. Western society has turned to food as the source of these enhancers. These products are called differently: vitamins, dietary supplements, functional foods, “nutraceuticals”, phytochemicals, bio-chemopreventants and branded food [Blecha and Wawer 2011, ENA 2017, FDA 2018]. These terms vary in meaning from country to country, as do the regulations for these substances. According to Zeisel [1999], dietary supplements are ingredients extracted from food, herbs and plants, which are taken without further modification outside of food in order to obtain presumed health benefits. The term dietary supplements was first formally defined in the USA [Brower et al. 1998, Zeisel 1999]. However, the dose administered is not included in the definition. Zeisel [1999] proposes to define nutraceuticals as dietary supplements that provide a concentrated bioactive agent from food, presented in a non-food matrix and used to improve health at doses exceeding those that can be obtained from normal food.

Nutraceuticals are biologically active ingredients that can be present in functional or separate food and have a documented, and at the same time, beneficial effect on human health through their participation in metabolic processes [Audery et al. 2004]. Espin et al. [2007] consider nutraceuticals to contain pharmaceutical formulations containing food phytochemicals as active substances. Nutraceuticals in the USA, as food additives, also have other terms: therapeutic foods, phytochemicals, preventive substances, pharmaceutical foods (pharmafood), functional foods [Blecha and Wawer 2011]. The Act on food safety and nutrition [Dz.U. 2006, nr 171, poz. 1225] lists only three categories: dietary supplements, food for special nutritional uses, dietary food for special medical purposes [Rehniquist 2003, ENA 2017, FDA 2018]. It should be noted that the terms “dietary supplements” and “functional foods” are more frequently used in European

legislation [Verhagen et al. 2010, Błecha and Wawer 2011]. In Polish literature, we also find the term “enriched food” [Błecha and Wawer 2011]. In the opinion of Kosiorek et al. [2013], a nutraceutical is a food or substance isolated from the matrix of a food product, concentrated, having a health-promoting, preventive effect, in the form of capsules, pills, extracts and other similar forms of the medicines. These are products with intermediate characteristics between drugs and traditional food products, sold in various forms as pills, capsules, tablets, syrups and others. They are not recommended for consumption as conventional food in the form of meals or diet, only as food additives. They are sold as food without special certificates required for medicines. According to Reqnquist [2003], nutraceuticals are bio-substances or their preparations derived from raw materials of animal, vegetable and biotechnological origin, which were produced (isolated) using innovative technologies. Among the most frequently used and most recognized raw materials for the production of nutraceuticals, there are, among others: plant extracts, including herbs, fruits, eggs, colostrum, beekeeping products, etc. The term nutraceuticals has been used since the 1990s to describe dietary supplements or other foods in pharmaceutical form that have health-promoting properties (which brings health benefits).

Nutraceuticals have a specific definition other than those in other categories of food products, such as: food, dietary supplements, herbal products, functional foods and enriched foods [Błecha and Wawer 2011, Kosiorek et al. 2013, Sakthinathan and Nandhini 2017]. Nutraceuticals refer to substances used as part of a food containing ingredients that support the body's function, in addition to being nutritious. The range of these products is wide and diverse. Nutraceuticals include individual nutrients and biologically active phytochemicals, supplements, functional foods and herbal products [Błecha and Wawer 2011, FDA 2018]. Biologically active phytochemicals include phenolic compounds, polyphenols, anthocyanins, flavanones, isoflavones, ellagitannins, ellagic acid, resveratrol, proanthocyanidins, procyanidins, flavan-3-ols [Sakthinathan and Nandhini 2017].

Meanwhile, conventional knowledge in Europe introduces a strict distinction between nutrition/food and drugs or pharmaceuticals [ENA 2017]. According to this conventional view, foodstuffs provide nutrition in the form of substances needed for the human body for normal development and maintenance of body functions. On the other hand, medicines are always seen as therapeutic agents in terms of illness and health. The more knowledge was obtained about the health-promoting effects of food, the more apparently it blurred the strict dividing line between the two product groups. This notion reflects the nutraceutical combination of both the idea of nutrition and the concept of pharmaceuticals. This is now a well-established deadline [ENA 2016, 2017].

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Sometimes, this term is understood more broadly as all foods with special pro-health properties, regardless of their form [Krochmal-Marczak et al. 2017, Martínez-Pineda et

al. 2019, <http://www.nutrition.org.uk>]. Their main source is primarily plant products, and to a lesser extent, microorganisms and animal products. Nutraceuticals is a term created from the combination of two words: nutrition and pharmaceutical. It means substances that can be considered as a food or a part of it, can help maintain the health and well-being of an organism by optimizing its function, as well as reduce the risk of and prevent from civilization diseases [Audery et al. 2004, Krochmal-Marczak et al. 2018]. According to Wildman [Audery et al. 2004], nutraceutical is an ingredient that is a common element for both foods for special nutritional purposes, functional food and dietary supplements. The term includes any biologically active substance that can strengthen, weaken or modify the physiological and metabolic functions of the body, and thus have beneficial effect on the body. The most commonly used and most recognized raw materials for the production of nutraceuticals include, among others: plant extracts, including herbs, fruits, eggs, colostrum, beekeeping products, etc. [Blecha and Wawer 2011, Trziszka and Cichocka 2018].

Substances that can be contained in nutraceuticals are: vitamins, minerals, polyphenols, e.g. vitamin E; flavonoids, e.g. flavonoids contained in the fruits of black cranberry, chokeberry; polyphenols, e.g. contained in a peel of navy grapes; or polyunsaturated fatty acids, e.g. omega-3 fatty acids contained in marine fish or chia plants [<http://www.nutrition.org.uk>]. One of the basic mechanisms of action of many of these substances is their antioxidant activity (scavenging free oxygen radicals). This leads to the protection of cellular structures against degeneration processes resulting from environmental pollution, aging processes and other processes adverse to health [Sawicka et al. 2013a, b, Krochmal-Marczak et al. 2017, 2018, Sharifi-Rad et al. 2019].

CLASSIFICATION

The nutraceutical industry concerns three main segments, which include: functional foods, dietary supplements and herbal/natural products [Blecha and Wawer 2011, Shashirekha et al. 2015]. The essential feature of nutraceuticals is their natural origin (Tab. 1).

Scientific research supports the biological activity of many food phytochemicals, but health claims attributed to final nutraceutical products sold on the market often have little or dubious scientific basis. *In vitro* tests are often performed, while human clinical trials are rare and equivocal. Some key issues, such as bioavailability, metabolism, dose and toxicity of these bioactive food compounds or nutraceuticals themselves, are not yet well understood. Among the phytochemicals in the nutraceutical industry, several groups of polyphenols are currently used (anthocyanins, proanthocyanidins, flavanones, isoflavones, resveratrol and ellagic acid). Therefore, scientific knowledge on the bioavailability and biological activity of these polyphenols was reviewed, as well as health claims (which are not always supported by scientific research) attributed to ingredients containing polyphenols ('fiction') [Espin et al. 2007, Quazi 2012, Santini and Novellino 2016, Santini et al. 2018]. The *in vitro* capacity of antioxidants, often used as a statement, may be irrelevant for the *in vivo* antioxidant activity. The bioavailability, metabolism and distribution of these polyphenols in humans are key factors that must be clearly estab-

lished in connection with the biological effects of these polyphenol-containing nutraceuticals [Bagchi and Nair 2016].

Table 1. Origin of selected nutraceuticals

Plant		Animal	Microbial
Allicin	Lignin	Choline	<i>Bifidobacterium bifidum</i>
Ascorbic acid	Luteolin	Coenzyme Q10	<i>Bifidobacterium longum</i>
α-tocopherol	Lutein	Conjugated linoleic acid – CLA	<i>Bifidobacterium infantis</i>
β-carotene	Lycopene		<i>Lactobacillus acidophilus</i> (LC1)
β-glucan	Minerals	Creatine	<i>L. acidophilus</i> (NCFB 1748)
β-ionone	Monounsaturated	Docosahexaenoic acid – DHA	<i>Saccharomyces boulardii</i> (yeast)
Capsaicin	Pectin	Eicosapentaenoic acid – EPA	<i>Streptococcus salvarius</i> (subs. <i>thermophilus</i>)
Cellulose	Phenolic acids,	Lecithin	
Daidzein	Phytic acid	Minerals	
Fatty acids	Phytosterols	Sphingolipids	
Gallic acid	Potassium		
Genistein	Protease inhibitors		
Geraniol	Saponins		
Glutathione	Sterile alcohol		
δ-limonene	Quercetin		
Hemicellulose	γ-tocotrienol		
Indol-3-carbinol	Zeaxanthin		
Isoflavones			

Source: Cieplucha [2004], Prabu et al. [2012], Bagchi and Nair [2016], Santini et al. [2018]

Table 2. Selected nutraceuticals

Isoprenoids, terpenes	Phenolic compounds	Proteins, amino acids	Carbohydrates and derivatives acids	Fat and lipids structurants Components	Minerals	Microorganisms
carotenoids, saponin, tocotrienols, tocopherols, simple terpenes	coumarin, tannins, lignin, anthocyanins, isoflavones, flavanols, flavones	amino acids, allyl, compounds, sulfur, capsaicinoids, folic acid, isothiocyanine, choline, indoles	ascorbic acid, oligosaccharides, non-starch polysaccharides (prebiotics)	PTS (n-3), PEP, CLA, JKT, sphingolipids, lecithin	Ca, Se, K, Cu, Zn,	probiotics, prebiotics

CLA – conjugated linoleic acid, JKT – colony forming units; PEP – phosphoenolpyruvate, PTS – phosphotransferase system

Source: Prabu et al. [2012], Trziszka and Cichocka [2018], Santini et al. [2018]

Nutraceuticals are mainly substances of vegetable origin – so-called phytochemicals. Citrus fruits – valuable because of the content of vitamin C, folates and fiber – also appear to be a source of biologically active compounds, so-called limonoids. There is also more and more evidence that monoterpenic limonene has anti-cancer properties. It is also believed that garlic, known for thousands years as the most potent natural antibiotic, can also be treated as a source of anti-cancer agents [Sakthinathan and Nandhini 2017, Socaci et al. 2017]. However, they can also be taken from raw materials of animal or microbiological origin. The most important groups of nutraceuticals are terpenoids and their derivatives, polyphenolic compounds, fatty acids and their isomers, carbohydrates, proteins and amino acids, minerals, microorganisms – prebiotics (Tab. 2). However, the main function of pre- and probiotics is to improve the immune system [Quazi et al. 2012, Bagchi et al. 2016, Garime and Monoj 2016, Santini and Novellino 2017, Santini et al. 2018]. In terms of health effects, nutraceuticals can be divided into five groups. The sixth group, the substance of the skin, the gloss of hair and nails, is now of great importance. Among the nutraceuticals with this effect, there are B vitamins and minerals (zinc, selenium, silicon [*lat. silicium*]), horsetail and nettle extracts. Nutraceuticals are obtained from various raw materials [Prabu et al. 2012, Krochmal-Marczak et al. 2013a, Sawicka 2016, Skiba and Sawicka 2016, Sharifi-Rad et al. 2019].

FOOD AS A SOURCE OF NUTRACEUTICALS

Nutraceuticals can occur in food in a variety of ways of the nutraceuticals contained naturally in food: those that support physical performance and functions of the digestive system, cardiovascular system as well as the immune system (Fig. 1) are sought after and commonly consumed. Due to the properties of nutraceuticals, the following food groups can be mentioned:

1. improving the functioning of the digestive system – yogurt and probiotic beverages, bread, breakfast cereals (pro- and prebiotic source) [De Felice 1995, Cieplucha 2004, Saluk-Juszczak et al. 2010, Prabu et al. 2012, Santini et al. 2018];
2. reducing overweight and obesity – food with reduced sugar and fat content, herbs as a source of appetite suppressants (e.g. HCA acid [hydroxycitric acid], dietary fiber), accelerating fat burning (e.g. L-carnitine), improving carbohydrate metabolism (e.g. chrome) [Ashvini et al. 2013];
3. reducing the risk of cardiovascular diseases (e.g. vegetable oils, olive oil, yogurts, cheese, juices, bread, chocolate, soy (source of phytosterols, stanols, n-3 fatty acids, dietary fiber, flavonoids and polyphenols, peptides, gamma-linolenic acid, gamma-aminobutyric acid [GABA]) [Rizzon et al. 2012, Ashvini et al. 2013, Socaci et al. 2017, Sawicka et al. 2018b];
4. preventing osteoporosis – soy, bakery and confectionery products, desserts, drinks (source of calcium, magnesium, prebiotics) [Sawicka 2016, Martínez-Pineda et al. 2019];
5. reducing the risk of cancer – soy, whole-grain bread, flour products; muesli bars (source of isoflavones, dietary fiber), green tea (source of catechins) [Ashvini et al. 2013, Pszczółkowski and Sawicka 2016, Santini et al. 2018];

6. anticancer properties – citrus fruits due to the content of vitamin C, folates, fiber as well as biologically active compounds – limonoids [Saluk-Juszczak et al. 2010, Martínez-Pineda et al. 2019];

7. improving the psychophysical efficiency – these are some juices, fruit drinks, infusions of herbs and other non-alcoholic beverages (energizing and isotonic) [Ashvini et al. 2013, Scalbert et al. 2011, Socaci et al. 2017];

8. in the treatment and prevention of diseases caused by hypercholesterolemia, currently the main role is played by drugs from the group of statins, however, the use of plant sterols and stanols increases the effectiveness of statin therapy and blood cholesterol lowering diets (linseed, corn oil, sunflower, soy, mustards and rapeseed oil) [Cieplucha 2004, Sawicka et al. 2013b, Krochmal-Marczak et al. 2018, Sharifi-Rad et al. 2019];

9. in the prevention of estrogen-dependent cancers; linseed as a source of precursors of enterodiol and enterolactone lignans, helpful in preventing cancer [Saluk-Juszczak et al. 2010, Krochmal-Marczak et al. 2017];

10. in the prevention of ocular diseases of old age: cataracts and age-related macular degeneration (AMD) have their department lutein and zeaxanthin together with natural antioxidants (vitamins C, E and beta-carotenes) [Ołędzka 2007, Saluk-Juszczak et al. 2010, Sharifi-Rad et al. 2019];

11. containing caffeine, taurine, glucuronolactone, sugars, a complex of vitamins and minerals [Ołędzka 2007, Sawicka 2016, Krochmal-Marczak et al. 2018, <http://www.nutrition.org.uk>].

Positive impact of such food on health depends, among others, on whether it is consumed regularly in the right amount and at the right time, or whether there are other ingredients in the diet that nutraceuticals could interact with, which could increase or decrease their health effects [Ołędzka 2007, Saluk-Juszczak et al. 2010, Krochmal-Marczak et al. 2018, Santini et al. 2018]. In contrast to functional foods, nutraceuticals are available in the form of tablets, syrups, powders or capsules containing food substances isolated from food, the positive effects on the body of which are confirmed in scientific research. Among the most frequently used and the most recognized raw materials for their production, we can mention, among others: plant extracts, including herbs, fruits, eggs, beekeeping products, etc. [Błęcha and Wawer 2011, Babbar et al. 2015, Shashirekha et al. 2015, Sawicka et al. 2016, Socaci et al. 2017].

BIOACTIVE SUBSTANCES

Ingredients of cereals, legumes, proteins, seafood as well as milk, carbohydrates and lipids are known and constantly evaluated due to their impact on human health as biofunctional compounds. References to fruits and vegetables, however, outweigh all other food groups, and thus their state of aggregation. Fruits and vegetables abound in the spectrum of such compounds that affect health, affect their bioactivity, instead of their consumption in fresh or processed form. Antineoplastic phenols e.g. from *Phyllanthus*, *Litchi chinensis*, phenols/flavonoids, hypoglycemic signal, as well as quercetin and hydroxycinnonates from sweet cherry fruits, mangosteen fruit xanthonenes,

pomegranate elagitan, succinic acid from sea buckthorn, watermelon, which relaxes muscles, soluble fiber cholesterol as well as sterols, card protection saponins, potato tuber hydrolysates that inhibit ACE (acetylcholinesterase, acetylcholine esterase, acetylcholine hydrolase) [Shashirekha et al. 2015, Sawicka et al. 2018a]. Antineoplastic ascorbic acid, carotenoids, including pro-vitamin A, are just a few examples of bioactive compounds that affect health. Hence, it is inevitable to avoid structural chemistry, influence the storage and processing conditions, factors favoring their bioavailability in food preparations, affecting human health. This combination of these compounds in the daily diet determines their suitability for the human body. The most important are the specific health benefits of consuming fresh or processed fruit, vegetables or other food products based on functional compounds [Skiba and Sawicka 2016, Bagchi and Nair, 2016, Krochmal-Marczak et al. 2017, Ziarati et al. 2017]. Relationships between biologically active compounds, raw materials and their healing and health properties are shown in Figure 1.

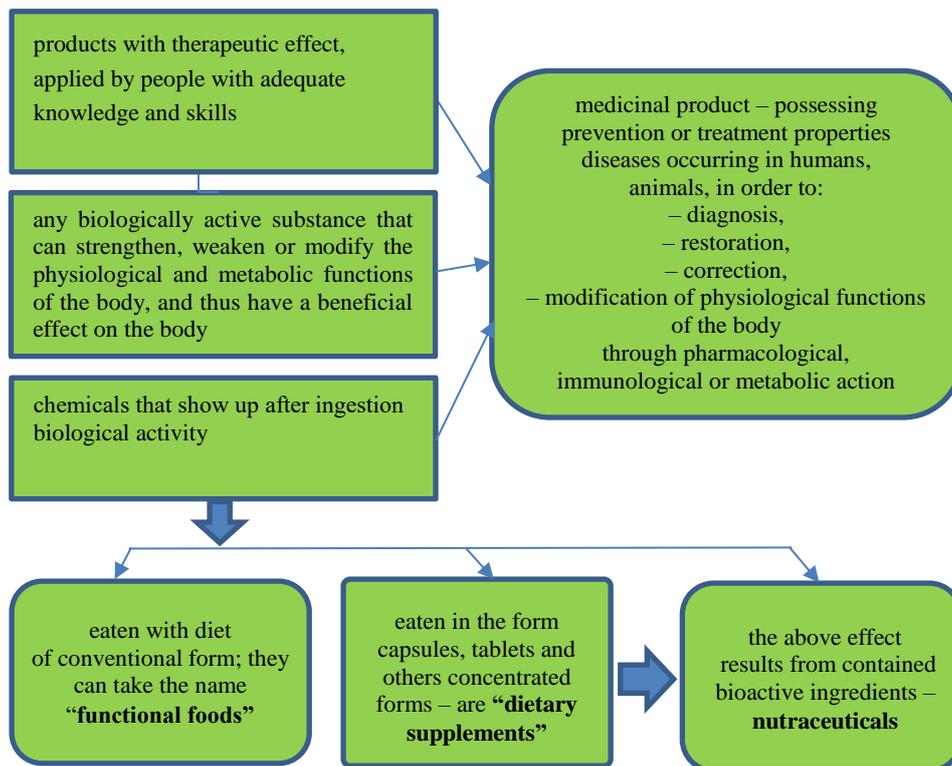


Figure 1. Bioactive substances – active – nutraceuticals „nutrition” + „farmaceutical”
Source: Babbar et al. [2015], Trziszka and Cichočka [2018]

Natural preservatives derived from plant extracts, such as phytochemicals and essential oils, are used against fungi growing on fruit and vegetables after harvest [Socaci et al. 2017,

Gómez and Martínez 2018]. The effectiveness of antimicrobial treatment depends on the type, species and strain of the main microorganism, in addition to environmental factors such as pH, air temperature, atmospheric composition or initial microbiological load of the food material. There are many environmental factors, and one of the most important is the interaction between phytochemicals and the growth of microorganisms. Processing the food containing phytochemicals should cause some changes in the content of phytochemicals. They are present in many food products, but they are lost by heat treatment, e.g. sterilization, pasteurization or dehydration [Gómez and Martínez 2018]. The potential use of plant extracts as natural antimicrobial agents in food preservation is the basis of many applications, such as grape or rosemary extracts, which can be used as food preservatives. Flavonoids usually occur as glycosides and aglycones in plant tissues and possess significant antioxidant properties as well as antimicrobial and insect repellent properties. These compounds and their antimicrobial activity are useful as a preservative to extend shelf life and food safety. Flavonoids play an important role in biological activities, including antiallergic, antiviral and antifungal. They are also present in various popular fruits and vegetables (apples, grapes, lemons, tomatoes, onions, lettuce and broccoli). Plant flavonoids (isoflavonoids, flavan, flavanones) are plant antifungal agents [Socaci et al. 2017]. The antifungal activity of flavonoid compounds plays an important role between plant microorganisms and host plant defense systems. Saponins and flavonoids are found in fruits and vegetables and generally form a soapy foam from parts of plants after extraction. Thiosulfinates are derived from the hydrolysis products of garlic and onions. They have a strong potential to cause antimicrobial action against pathogenic microorganisms. Broccoli, Brussels sprouts, common brown mustard (Chinese mustard), white mustard and horseradish contain glucosinolates, which also have a wide range of antibacterial activity [Sawicka et al. 2013a, Gómez and Martínez 2018].

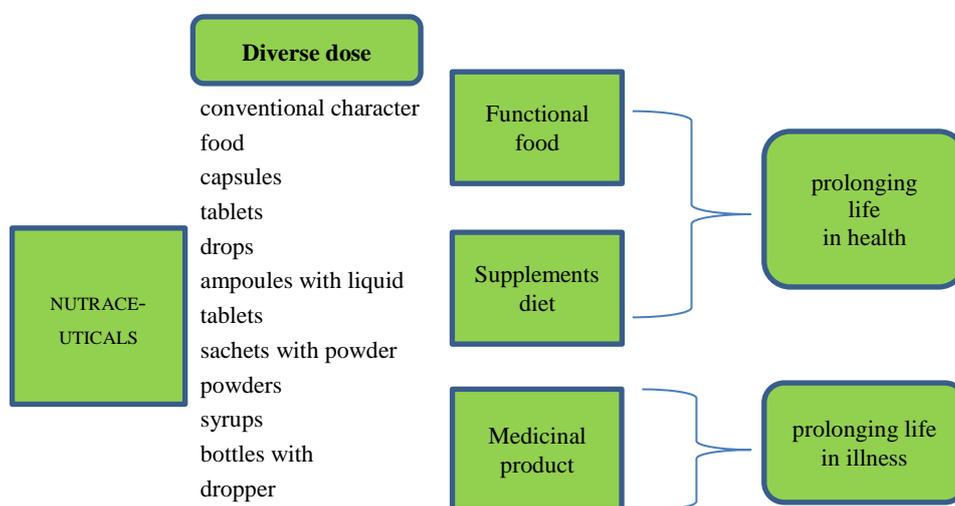


Figure 2. Nutraceuticals and their importance in human nutrition
 Source: Soquetta et al. [2018], Trziszka and Cichocka [2018]

Functional foods and diet supplements prolong the human life, while medicinal products prolong life in illness [Sousa et al. 2014, Soquetta et al. 2018] (Fig. 2).

Bioactive substances in food and pharmacy are shown in Table 2 and Figure 2.

The types of food and natural nutraceuticals found in foods are provided in the Table 3.

Table 3. Food products, in which nutraceuticals are naturally contained in significant quantities

Food products	Nutraceuticals occurring naturally in food
Onion	allyl garlic sulfur compounds
Soy and other leguminous plants	protein, isoflavones, e.g. genistein, daidzein protease inhibitors, phytosterols, saponins, phenolic acids, phytic acid, isoflavones
Cruciferous vegetables	glucosinolates, isothiocyanates, indoles, carotenoids
Wheat bran	β -glucan cereal products, beef and dairy products conjugated linoleic acid (CLA)
Grapes (skin),	red wine resveratrol
Tea, berries, red wine	polyphenolic compounds: catechins, anthocyanin's
Kale, spinach, corn, eggs,	citrus lutein, zeaxanthin
Vegetable oils (linseed, evening primrose, amaranth)	lignin's, fatty acids: ALA, alpha-linolenic, squalene
Fish oil, eggs	EPA and DHA
Eggs	ovophospholipids, fatty acids including ALA, DHA, biopeptides, vitamins

Source: Krochmal-Marczak et al. [2017], Sawicka et al. [2013a, 2016, 2018b], Gómez and Martínez [2018], Martínez-Pineda et al. [2019]

Natural preservatives derived from plant extracts, such as phytochemicals and essential oils, are used against fungi growing on fruit and vegetables after harvest [Socaci et al. 2017, Gómez & Martínez 2018]. The effectiveness of antimicrobial treatment depends on the type, species and strain of the main microorganism, in addition to environmental factors such as pH, air temperature, atmospheric composition or initial microbiological load of the food material. There are many environmental factors, and one of the most important is the interaction between phytochemicals and the growth of microorganisms. Processing food containing phytochemicals should cause some changes in the content of phytochemicals. They are present in many food products, but they are lost by heat treatment, e.g. sterilization, pasteurization or dehydration [Gómez & Martínez 2018]. The potential use of plant extracts as natural antimicrobial agents in food preservation is the basis of many applications, such as grape or rosemary extracts, which can be used as food preservatives. Flavonoids usually occur as glycosides and aglycones in plant tissues and possess significant antioxidant properties as well as antimicrobial and insect repellent properties. These compounds and their antimicrobial activity are useful as a preservative to extend shelf life and food safety. Flavonoids play an important role in biological activities, including antiallergic, antiviral and antifungal. They are also

present in various popular fruits and vegetables (apples, grapes, lemons, tomatoes, onions, lettuce and broccoli). Plant flavonoids (isoflavonoids, flavan, flavanones) are plant antifungal agents [Socaci et al. 2017]. The antifungal activity of flavonoid compounds plays an important role between plant microorganisms and host plant defense systems. Saponins and flavonoids are found in fruits and vegetables and generally form a soapy foam from parts of plants after extraction. Thiosulfinates are derived from the hydrolysis products of garlic and onions. They have a strong potential to cause antimicrobial action against pathogenic microorganisms. Broccoli, Brussels sprouts, commonly brown mustard (Chinese mustard), white mustard and horseradish contain glucosinolates, which also have a wide range of antibacterial activity [Sawicka et al. 2013a, Gómez and Martínez 2018].

Various nutraceutical properties of the olives are attributed to different oil compositions and a variety of active substances [Socaci et al. 2017]. Nine smaller varieties of Iranian olives were tested, i.e. Tarom (T) varieties. The characteristics of these minor varieties (T10, T15, T16, T17, T18, T20, T22, T23, T24) along with 3 main Iranian and 4 Mediterranean varieties with 11 chromosomal SSR markers showed remarkable diversity among them. Most Iranian varieties (T) were characterized by high oil yield and high total phenol content (TPC) comparable to Mediterranean olives. Varieties T18 and T22 had higher content of oleic acid (OIA) and T24 and T18 – the lowest content of linoleic acid (LiA), in comparison with Mediterranean varieties. In turn, T18 showed the highest OIA/LiA ratio. The T24 variety was characterized by an extremely high phenol content. In turn, the T22 strain showed significantly higher antioxidant index of phenol than Mediterranean varieties. Radical Scavenging Activities (RSA) did not suggest a linear correlation between TPC and the antioxidant capacity of the tested varieties. Given the nutraceutical potential, the Iranian (T) varieties perform the dominant over Mediterranean varieties, and therefore deserve to be included in olive improvement programs [Ashwini et al. 2013, Socaci et al. 2017]. Examples and characteristics of natural food existing bioactive components was given in Table 4.

The glucosinolates contained in cabbage plants – previously considered anti-nutritional compounds – are currently of increasing interest due to their possible beneficial effects. Cruciferous vegetables contain glucosinolates with antineoplastic properties [Sawicka et al. 2013a, 2013b, Krochmal-Marczak et al. 2017, Sharifi-Rad et al. 2019].

HEALTHY PROPERTIES OF NUTRACEUTICALS

Among nutraceuticals, there are so-called non-essential food ingredients, i.e. those that are not classified as neither vitamins nor minerals. They belong to different groups in chemical terms, but most often they are derived from carbohydrates or amino acids. Most of them occur in our diet in a natural way. They can also be components of the human body performing a specific function. For example, they may be important cofactors in a variety of biological reactions, they may be precursors in the synthesis of molecules that are biologically or structurally important [Ashwini et al. 2013, Babbar et al. 2015, Pszczółkowski and Sawicka 2016, WHS 2019].

Table 4. Examples and characteristics of natural food existing bioactive components

Product	Component bioactive	Health effect
Soy and soy products	Protein lowering the level, soy-bean products contain a plethora of bioactive phytochemicals such as isoflavones, saponins, phytic acids, phytosterols, trypsin inhibitors, and peptides	Genistein and daidzein fill a gap in the protein diet of vegetarians. Lack of endogenous estrogen affects the activity and bioavailability of isoflavones. The method of therapeutic action may consist of stimulation of estrogen receptors or by the absence of estrogen receptors. Due to the content of isoflavones, it helps in preventing cancer by interrupting the breakdown of the extracellular matrix surrounding growing vessels and tumors, lowering blood lipid and insulin levels by regulating lipid and glucose metabolism, alleviating menopausal symptoms and osteoprotective effects by modulating estrogen receptors, it also has antihypertensive effects
Cranberry juice	Proanthocyanidins, particularly flavan-3-ols, A-type procyanidins (PACs), anthocyanins, benzoic acid, and ursolic acid. Cranberry flavan-3-ols are present as monomers, oligomers, and polymers	Reducing the risk of infection; has anti-inflammatory effect, clears blood vessels, increases plasma antioxidant activity and decreases lipid oxidation; reduces the concentration of LDL cholesterol in the blood
Green tea, tomato juice	Catechin lycopene	Catechin reducing the risk of diseases (cancer, prostate), has antibacterial, antioxidant, antiviral, anti-inflammatory, anti-fungal, anti-mutagenic, anti-thrombotic, anti-atherosclerotic effect, lowering blood pressure, reducing cholesterol. Lycopene protects against oxidative damage to lipids, proteins and DNA. Lycopene is a strong quencher of singlet oxygen (reactive oxygen) and may have stronger antioxidant properties than other major plasma carotenoids
Milk products	Fermented probiotics	Reducing the risk of diseases
Garlic, onion	Over 200 biologically active substances, including the most important are sulfur compounds	Large intestine; onions and garlic reduce the risk of prostate cancer. Garlic can help reduce the incidence of precancerous cancers (polyps) in the large intestine. Eating garlic reduces calcium deposits and the size of the arterial plaque in the coronary arteries, which prevents unhealthy blood clotting and improves blood circulation
Jerusalem artichokes	FOS	Reduction of cholesterol ovofosfolipides
Eggs (egg yolk)	WNKT	Regeneration of the body, lowering blood pressure; reduction of cholesterol and blood pressure

FOS – Fructo oligosaccharides WNKT – polyunsaturated essential fatty acids

Source: Sawicka et al. [2016, 2017, 2018a], Gómez and Martínez [2018], Trziszka and Cichocka [2018]

Nutritious features of nutraceuticals are given on their packaging or in their advertisements and are referred to them as health claims. These are statements about pro-health activity, e.g. “calcium strengthens bones” or “omega-3 fatty acids reduce the risk of another infarction” [Sawicka et al. 2015, 2018a, Krochmal-Marczak et al. 2017, Soquetta et al. 2018].

Difference between the drug and the nutraceutical is the subject of debate among scientists and health authorities. It is generally accepted that nutraceuticals should only contain doses lower than those contained in medicines and demonstrate higher level of safety of use (especially long-term) than typical medicines [Shashirekha et al. 2015, Sakthinathan and Nandhini 2017, <http://www.nutrition.org.uk>]. Hence, in most cases and importance are compared to the role of vitamins. These substances, however, are not classified as essential ingredients, because their synthesis in a healthy body is usually sufficient for proper functioning [Ashwini et al. 2013, Krochmal-Marczak et al. 2018].

The glucosinolates contained in cabbage plants – previously considered anti-nutritional compounds – are currently of increasing interest due to their possible beneficial effects. Cruciferous vegetables contain glucosinolates with antineoplastic properties [Sawicka et al. 2013a, 2013b, Krochmal-Marczak et al. 2017, Sharifi-Rad et al. 2019].

HEALTHY PROPERTIES OF NUTRACEUTICALS

Among nutraceuticals, there are so-called non-essential food ingredients, i.e. those that are not classified as neither vitamins nor minerals. They belong to different groups in chemical terms, but most often they are derived from carbohydrates or amino acids. Most of them occur in our diet in a natural way. They can also be components of the human body performing a specific function. For example, they may be important cofactors in a variety of biological reactions, they may be precursors in the synthesis of molecules that are biologically or structurally important [Ashwini et al. 2013, Babbar et al. 2015, Pszczółkowski and Sawicka 2016, WHS 2019].

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ASPECT OF PACKAGING

The nutritional and health claims should be placed on the packaging of nutraceuticals or food that is their source. The latter take on special significance as they suggest the influence of the active ingredient contained in the supplement on the proper function of the organism and inform about their intended use. A producer, who puts an appropriate nutrition or health claim on the label of a unit packet, should justify the use of this statement, namely he should provide adequate evidence to prove its impact on the human body. Nutrition and health claims must not mislead the consumer, may not raise doubts about food safety, encourage excessive consumption, or refer to changes in the body's functioning in a way that is fearful for the consumer. The use of claims may be based on generally recognized scientific evidence that the ingredient or lack thereof has beneficial effects, provided it is present in the product in the appropriate quantity and proportion. The producer must prove that the rational amount of the product consumed contains the amount of ingredient that will act in accordance with Regulation (EC) No. 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims on food [Regulation (EC) No 1924/2006, Skiba and Sawicka 2016]. The high demand for nutraceuticals indicates their further intensive development. These products are interesting, both for consumers and food producers. Nutritional research will play an important role in the further development of nutraceuticals and functional foods. Many functional food ingredients are known for their pro-healthy activity, but an even larger group of compounds is little or not fully understood in terms of their health-promoting properties [Almodovar 2010, Ashwini et al. 2013, <http://www.nutrition.org.uk>].

COMPOUNDS RECOVERED FROM FOOD WASTE

The food waste such as fruit-processing industry generates enormous solid waste in the form of pomace, peels, kernels, and pulp following the industrial processing of fruit juices. The fruit residues are not only by products of industry, but are also found in the household kitchens, restaurant trash bins, hotel, juice, local shops and also contribute significantly to the municipal solid waste [Oltjen et al. 1977]. Recently, due to economic issues and waste technology, by-products are receiving increased consideration by livestock manufacturers and animal nutritionists, and bred animals especially [Bovard et al. 1977]. One of these products is apple pomace that is alternative by-product obtained from apple juice industries in huge amounts and by fruit juice shops in other scale annually. Chemical composition of final pomace is linked to the morphology of original feed stock and the extraction technique used. According to NRC 2001, apple pomace (AP) in some regions is very low in protein (contains only 6.4% protein on DM basis) and it also serves as a useful energy source for ruminants [Oltjen et al. 1977, Gholizadeh and Ziarati 2016]. Other studies revealed that AP supplemented with natural protein was comparable to protein enriched corn silage Ashwini et al. [2013]. In contrast, mean level of protein and mineral elements were determined from apple pomace the fruits of which are cultivated in Fars province in Iran showing much higher protein (22.1%) and very high zinc, iron and remarkable calcium contents [Gholizadeh and Ziarati 2016].

Another important abundant nutritive fruit waste is grapes that are consumed both as fresh and as processed products such as wine, jam, juice, jelly, grape seed extract, dried grapes, vinegar and grape seed oil. The cultivation of grapes is widely spread around the world [FAO-OIV 2016]. Ziarati et al., in 2017 worked upon protein, mineral contents of pulps, seeds and peels of 5 different grape pomaces (Red Rishbaba, Shahroudi, Shoush Aroos, Yaghouti and Askari) in Iran based on dry weight. Comparing with Dietary Reference Intakes (DRI) [National Academy of Sciences 2011], the iron content in grape pomace found in current study (46.02 mg/100 g) supplies the adult daily requirements for iron (8 mg/day for men and 8 to 18 mg/day for women) [Rizzon and Miele 2012, Souza et al. 2014, Sakthinathan and Nandhini 2017]. Due to the results of mineral analysis shown in this research [Ziarati et al. 2017], iron, copper, potassium, zinc, manganese and calcium were present at much higher concentrations in comparison to other studies in Brazil and Libya [Salem et al. 2015, Ziarati et al. 2017]. The outcome of these researches is very impressive as in Iran and many developing countries, the considerable uses of food industries and agricultural waste are animal feed or as fuel in factories. In many cases, farmers attempted to burn these additional appearance materials, which leads to environmental pollution and in other hand, reducing the fertility of the ground [Lahiji et al. 2016]. Another nutritive fruit waste is pomegranate peels and seeds, as a by-product of pomegranate juice and concentrate industries, present a wide range of the pharmaceutical and nutraceutical properties [Kaderides et al. 2015]. On the whole, supplement ingredients may contain traces, minerals, vitamins, herbs or other herbal medicine or herbal plants, amino acids, enzymes, organ tissues, gland extracts, or other dietary substances, which are mainly derived from food and agricultural waste materials. They are in different available forms in any country and include powders, tablets, capsules, liquids, extracts, and concentrates [Babbar et al. 2015, Kaderides et al. 2015, Sawicka 2016].

Socaci et al. [2017] showed that waste from fruit and vegetable processing contains valuable particles (antioxidants, dietary fibers, proteins, natural dyes, aromatics, etc.) that can be extracted, purified and valorized in value-added products. This is the basis for regaining the huge potential of food waste and using it as a source of antioxidants and opening up the possibility of their extraction and purification. It turns out that fruits and vegetables, as well as roots and tubers have the highest rate of food waste. The FAO-OIV [2016] announced that global quantitative loss and waste of root crops, fruit and vegetables is 40–50% per annum [Abdrabb and Hussein, 2015]. Disposal of such quantities of waste is not only a challenge for food processors, but is also a matter of key importance at the international level due to environmental pollution and economic aspects [Oltjen et al. 1977, Rizzon and Miele 2012]. Research by many authors [Sawicka et al. 2013a, b, Skiba and Sawicka 2016, Ziarati et al. 2017, Sharifi-Rad et al. 2019] has shown that waste of plant origin should be reconsidered and recognized as renewable sources of valuable molecules that can be successfully extracted, purified and valorized in various fields, including the food, cosmetics, pharmaceutical and chemical industries, etc. For example, the search for non-toxic natural compounds with antioxidant activity is gaining more and more attention, especially due to consumers' awareness of the direct relationship between food (diet) and health [Rizzon and Miele 2012, Sousa et al. 2014, Lahiji et al. 2016, Krochmal-Marczak et al. 2017, Socaci et al. 2017]. Introducing the antioxidant compounds into the diet, such as polyphenols, is an effective way of combat-

ing the negative effects caused by the excess of reactive oxygen species (ROS) in the body. Oxidative stress caused by ROS is considered to be one of the main factors causing chronic diseases (cancer, diabetes, cardiovascular diseases or neurodegenerative diseases) [Socaci et al. 2017]. In the case of fruit and vegetables, there is a large amount of antioxidant compounds, usually in skins, grains or seeds, i.e. parts that are removed during processing and become waste [Sousa et al. 2014, Ferrentino et al. 2018]. Cheok et al. [2018] consider that currently recovering bioactive compounds from fruit waste that is beneficial for health is a research trend not only to reduce the burden of waste, but also to meet the society's intense demand for phenolic compounds that are thought to have a protective effect against chronic diseases. Due to this new proposed culinary method, the potassium content of potatoes is reduced to an acceptable level. In addition, the technique maintains a low potassium content even after frying potatoes, thus enabling the inclusion of potatoes in the CKD diet [Sawicka et al. 2016, Martínez-Pineda et al. 2019].

Fruit and vegetable by-products (FVB) are abundant nutrients and parenteral compounds that contribute to intestinal health, weight control, lowering cholesterol in the blood and improving the control of glycemic and insulin responses. Due to the positive effects of FVB fibers and bioactive compounds when digesting glycemic carbohydrates such as starch, baked goods are ideal food systems for FVB, as most of them have a high glycemic index. Gómez and Martínez [2018] report that this is an area of new, recently discovered significance, crucial for the environment, economy and health all over the world. However, the use of FVB in baked goods leads to a loss of acceptability, in many cases due to a lack of understanding of the physical structure and composition of FVB and their impact on food quality. Therefore, these compounds can be extracted from fruit and vegetable wastes and re-used in other food products as functional ingredients capable of giving certain characteristic qualitative criteria, while also providing benefits to human health due to their antioxidant properties. The challenge to recover these compounds is to find the most suitable and environmentally friendly extraction technique capable of achieving maximum extraction efficiency without compromising the stability of the extracted products [Sousa et al. 2014, Gómez and Martínez 2018, Ferrentino et al. 2018].

NUTRACEUTICAL AND SUPPLEMENTS MARKET

The nutraceutical market is currently developing very dynamically. At present, the segment of functional food and nutraceuticals belongs to the most dynamically developing branches of the food industry. The annual sales volume is not in millions, but in billions of dollars. Nutraceuticals are biologically active ingredients that can be found in functional foods or separately, and have a significant beneficial effect on health through their participation in metabolic processes. Nutraceuticals are available in the form of tablets, syrups, powder, capsules containing active substances isolated from food, which have a positive effect on the human body. The most recognizable raw materials for their production are: plant extracts, including spices, medicinal plants, fruits, eggs, beekeeping products, etc. The high demand for nutraceuticals predicts their further intensive development. Both consumers and food producers are interested. In the further development of nutraceuticals and functional foods, scientific research will play a significant role. Many functional food ingredients are known for their pro-health activity, but even

larger group of compounds is little or not fully understood in terms of their health-promoting properties [Babbar et al. 2015, Ashwini et al. 2013, Gómez and Martínez 2018, <http://www.nutrition.org.uk>].

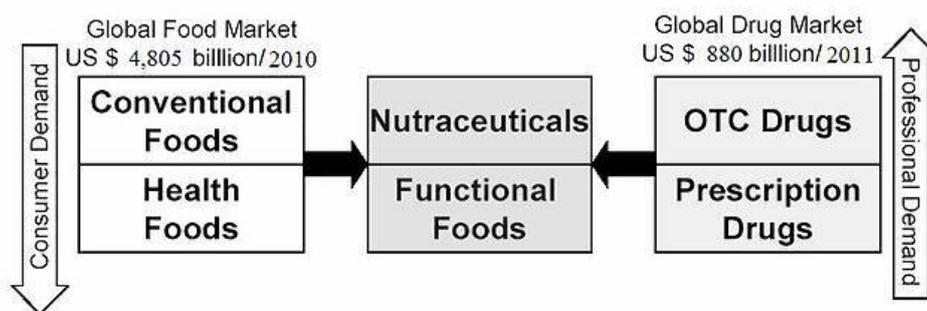


Figure 3. Growth in the global nutraceutical food market
Source: according Prabu et al. [2012]

27–40 various scientific organizations, government agencies, have increased the popularity of nutraceuticals and functional foods in the public sector. Awareness raising in public health, an aging population, escalating healthcare costs, the latest advances in research and technology, changes in government regulations and accountability, global market expansion, nice media and numerous scientific evidence contribute to the popularity of so-called “functional food”. Recognition of the functional diversity of food and nutraceutical composition will provide this industry with the opportunity to provide consumers with many new products that can be developed into specialized markets. Dietary supplements in the United States are governed by the DSHEA [Dietary Supplement Health and Education Act] adopted by the US Congress in 1994, which recognizes that dietary supplements play an important role in promoting health, and thus opens the way for consumers to obtain the necessary information to make food choices [DSHFA 1994, Rehnquist 2003, Prabu et al. 2012]. The DSHEA [1994], adopted to manage the human nutraceuticals market, does not allow the FDA [2019] to consider a new product as a “medicine” or “food additive” if it is covered by the definition of “dietary supplement”, which includes, among other things, all possible dietary ingredients as well as concentrates, ingredients, extracts or metabolites of these ingredients [Prabu et al. 2012]. With the adoption of the DSHEA Act, the definition of nutraceuticals was extended to include: vitamins, minerals, herbs and other botanicals, amino acids and all dietary substances for human use to supplement the diet by increasing total dietary intake to comply with regulations [Sawicka et al. 2016, Ferrentino et al. 2018, Gómez and Martínez 2018]. In Poland, the Act was adopted on August 25, 2006 on food and nutrition safety [Dz.U. 2017 poz. 149 i 60]. The provisions of this Act relate, among others, to: additives and food enzymes, flavors and solvents, food contaminants, food irradiation with ionizing radiation, food labeling and nutrition and health claims [Sawicka et al. 2016, Ferrentino et al. 2018, Gómez and Martínez 2018].

The diet supplements market will grow by around 8% annually by 2021. The most frequently purchased products are currently vitamin and mineral products, e.g. with magnesium or vitamin D [Sawicka 2016]. They constitute 26 percent of the entire market. USA, Japan and Switzerland lead the way in the production of nutraceuticals. Japan is currently the only country where the production and marketing of these products is strictly controlled. Only after a thorough check are they allowed on the market with the inscription FOSHU – Food for Specified Health Use (food with special health values). In the US, 60 million inhabitants regularly use nutraceuticals, spending over \$ 12 billion a year [Prabu et al. 2012]. In addition, the following are popular: immune-stimulants (22%), probiotics (20%), products strengthening the body (16%) as well as vitamins and minerals for adults (about 16% each). Also, products that stimulate immunity and omega-3 acids are also very popular. Among the wide range of nutraceuticals, following can be mentioned: colostrin (extract of colostrum bio-peptides) used in the prevention of Alzheimer's disease, yolk oval phospholipids, abundant in n-3 fatty acids and vitamins used in developing natural immunity and regeneration of the body after diseases (initium preparation), aronia preparations used in the prevention of heart disease and a whole range of herbal preparations. Mixtures of nutraceuticals and their interactions are of particular interest, especially on the carrier of functional foods [Sawicka et al. 2016, 2017, Ferrentino et al. 2018, Gómez and Martinez 2018].

The book Baghi and Nair [2016] provides critical information from the conceptualization of new products for marketing, aiming at a solid understanding of the whole process by detailed discussion of key concepts, namely innovation, regulation, production, quality control and marketing. The diet supplements market will grow by around 8% annually by 2021. Currently, it is worth PLN 3.5 billion. The most frequently purchased products are vitamin and mineral products, for example with magnesium or vitamin D. They constitute 26% of the entire market. In addition, the following are popular: immune-stimulants (22%), probiotics (20%), products strengthening the body (16%) and vitamins and minerals for adults (16%). Strengthening immune products and omega-3 acids are also well-selling [<http://www.nutrition.org.uk>]. More and more people are trying to eat healthy food, lead an active lifestyle and use supplements that enrich their diet. The whole market of dietary supplements has, according to PMR, an estimated value of approx. PLZ 2.5 billion. Approx. 60% of sales are for pharmacies and other sales networks of health products not for athletes. It is estimated that the sports part of this market is PLZ 1 billion, and the growth rate is 20–30% per year. These supplements are most often purchased by consumers in special stores with sports nutrition. For example, over 70% of Poles take diet supplements, and most people buy them after the age of 50 and 70, while sports nutrition enjoys the greatest interest of young generation [FAO-STAT 2018]. The food market is demanding, and consumers are constantly looking for new products and products that have a positive impact on their health and form. Responding to the needs and trends on the food market, the International Fair has been extended to the nutraceutical sector [Babbar et al. 2015, <http://www.nutrition.org.uk>].

BIOAVAILABILITY OF NUTRACEUTICALS AND UNDESIRABLE EFFECTS ASSOCIATED
WITH THEIR CONSUMPTION

Bioavailability and metabolism are key factors in understanding the biological effects of these nutraceuticals [Sawicka et al. 2016, Sakthinathan and Nandhini 2017]. Preparations of plant origin exhibiting antiplatelet properties may become in the near future an important element in the prevention of cardiovascular diseases. Due to the multidirectional protective effect of polyphenols on the cardiovascular system, the preparation of new prophylaxis and treatment strategies in cardiovascular diseases using plant polyphenols is increasingly being considered. However, it should be remembered that bioavailability is an important element in assessing their biological properties *in vivo*. The metabolism of polyphenolic compounds is multistage and involves various mechanisms, which raises the fear of limiting intestinal absorption. Furthermore, the lack of agreement between *in vitro* and *in vivo* test results and the insufficient number of multi-center clinical trials may also be a problem [Kosiorek et al. 2013].

There are also warnings in promoting the use of nutraceuticals. It turns out that antioxidants in excessive doses can be pro-oxidants, free radical scavengers can e.g. reduce the effectiveness of cancer therapy. They can excessively reduce blood clotting in combination with other drugs, e.g. ASA, and also make it more difficult to stop bleeding after surgery. However, the side effects of using nutraceuticals at high doses (the so-called accumulation effect) are not yet fully understood [Długosz 2007, Kosiorek et al. 2013].

Polyphenolic compounds are of particular interest as nutraceuticals. These compounds have antioxidant properties and scavenging free radicals harmful to health. As antioxidants, they prevent the oxidation of cholesterol, which causes blood vessels to narrow, and inhibit platelet aggregation, improve epithelial endurance, and increase vascular diameter, blood flow, and lower blood pressure. The health-promoting properties of polyphenolic compounds are described in specialized databases, e.g. Phenol-Explorer [Neveu et al. 2010], or in many other useful studies on the importance of polyphenols in the prevention and treatment of diseases [Mueller 1999, Verhagen et al. 2010, Scalbert et al. 2011, Kosiorek et al. 2013, Sakthinathan and Nandhini 2017]. The soy isoflavones also act as endocrine disruptors, they also have some negative effects. Fears regarding thyroid dysfunction were also raised [Santini et al. 2018].

Knowledge about the effects of nutraceuticals on the human body is not fully understood, therefore there are still more questions than answers [Andlauer and Furst 2002, Kosiorek et al. 2013].

Which of the nutraceuticals and in what diseases do they have preventive and pro-health effects?

What are the contraindications or quantitative restrictions on their use?

Are single compounds or mixtures of them beneficial?

To what extent can the beneficial bioactive effects of nutraceuticals be preserved during the technological process?

There are also warnings in the widespread use of nutraceuticals [Skibola and Smith 2000, Bloch 2000, Sakthinathan and Nandhini 2017], such as: excessive doses of antioxidants may be pro-oxidants, free radical scavengers may reduce e.g. the effectiveness of cancer therapy. They may also reduce the blood coagulability excessively in combination with other drugs, e.g. ASA, and may also hinder bleeding after surgery. The side

effects of using nutraceuticals in high doses (accumulation effect) are not yet fully understood [Długosz 2007, Kosiorek et al. 2013, EMA 2019].

Bioactive components of the diet can directly effect on the process of gene expression, acting as nuclear receptor ligands. In Gętek et al. [2013] opinion, sensor receptors sensitive to dietary components are sensor receptors. This group includes PPAR receptors (peroxisome proliferator activated), responsible for energy metabolism, and LXR (liver X receptor), FXR (farnesoid X receptor) and RXR receptors, responsible for cholesterol metabolism.

The messages for industry are: (a) the industry must develop patented pharmaceutical products and (b) it must develop the ability to demonstrate clinical benefit from such products. Currently, food and pharmaceutical companies do not have sufficient necessary knowledge and must quickly and effectively acquire it to join the nutraceutical revolution [Sakthinathan and Nandhini 2017].

CONCLUSION

The nutraceuticals are bioactive substances, and their components are characterized by either recognized therapeutic activity or chemically defined substances with generally accepted characteristics to contribute to their therapeutic activity. There is a growing interest in nutraceuticals that provide certain health benefits and which may be an alternative to traditional medicine in the future. By using nutraceuticals, it may be possible to reduce or eliminate the need for conventional drugs and reduce the adverse effects of conventional foods. Nutraceuticals give physiological benefits or provide protection against chronic diseases and play a beneficial role in various types of disease and disorders. However, even a large group of compounds is little researched in terms of their health-promoting properties, storage conditions and requires definition of legal aspects.

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Streszczenie. Wzrost świadomości konsumentów na temat żywności i zdrowia doprowadził do wzrostu zapotrzebowania na żywność zawierającą związki biologicznie czynne, zwłaszcza przeciwutleniacze, które mogą pomóc organizmowi człowieka zwalczać stres oksydacyjny. Odkryto wiele niekonwencjonalnych lub nowych źródeł przeciwutleniaczy, co jest priorytetem nie tylko dla przemysłu rolno-spożywczego, lecz także farmaceutycznego. Wykazano, że nie tylko surowce, lecz także odpady z przetwórstwa owoców i warzyw zawierają cenne cząsteczki, takie jak białka, niezbędne aminokwasy, przeciwutleniacze, włókno dietetyczne, naturalne barwniki lub związki aromatyczne, które mogą być ekstrahowane, oczyszczane i modernizowane w produktach spożywczych lub farmaceutykach o wartości dodanej. Jest to podstawa ogromnego potencjału surowców roślinnych i biotechnologicznych, a także odpadów spożywczych do wykorzystania jako źródeł przeciwutleniaczy.

Słowa kluczowe: związki bioaktywne, przeciwutleniacze, naturalne barwniki, wykorzystanie odpadów spożywczych, funkcjonalne składniki żywności, korzyści zdrowotne

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