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Potential utilisation of vegetables and mushrooms as components of functional food

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ABSTRACT

The importance of functional products on the world food market is increasing systematically. This has resulted from enhanced consumer awareness that health improvement may be attained through appropriate nutrition. Functional products are targeted to different groups of consumers who have increased nutrient requirements or are designed to improve specific functions of the organism. The market for functional food is also developing in Poland, but its growth rate is much slower than in other European countries. Moreover, knowledge on issues concerning functional food among Polish consumers is also low. Vegetables and mushrooms occupy an important position among functional food products due to their contents of many bioactive components that have a beneficial effect on human health and sense of well being. Vegetables in an everyday diet are natural sources of dietary fibre, vitamins, minerals, anthocyanin, carotenoids and substances with an anti-carcinogenic effect. The fruiting bodies of both cultivated and wild-growing mushrooms contain several active substances, including polysaccharides, triterpenoids, specific proteins and phenolic compounds. Their positive effect for humans results from the interaction of different active components contained in their fruiting bodies. Several health-promoting properties of mushrooms have been documented, including anti-cancer, immunostimulatory, antioxidant, antibacterial, antiviral and anti-diabetic effects. Consumers should have knowledge on the potential for health improvement thanks to the inclusion of vegetables and mushrooms in their everyday diets.

Key words: bioactive components, civilisation-related diseases, dietary fibre, health-promoting value, nutrition, polysaccharides

INTRODUCTION

Towards the end of the twentieth century, consumer awareness concerning the effects of nutrition on the state of health increased considerably. This brought along the demand for food products that would supply not only nutrients, but would also improve physical and mental efficiency (Bleiel 2010). Interest was raised in natural products, containing many active substances with documented effects, e.g. herbs and medicinal mushrooms (Barros et al. 2008). Demand has developed for food for special use, referred to as super-foods, medicinal, pharmaceutical, therapeutic or functional food. This food category includes vegetables and mushrooms as natural sources of components having a positive effect on the human organism.

The term *functional food* was coined in Japan in the 1980s. It was defined as Food for Specified Health Use (FOSHU) (Hardy 2000). That country

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also introduced legal regulations concerning such food (Arai 1996). Afterwards, interest in such foods developed in the USA and Europe. In recent years in Japan a new term has appeared, known as Food with Health Claims (FHC) (Ohama et al. 2006).

To date no specific uniform definition has been developed for functional food. According to Roberfroid (2002), food may be considered functional if its positive effect on one or more functions of the organism has been proven. According to the concept proposed by American and European experts, functional food should be an element of an appropriate diet, i.e. consumed on a regular basis and in normal amounts, while at the same time it should reduce the risk of specific diseases or exhibit an additional advantageous health effect apart from its basic nutritive value. For this reason these criteria are not met by capsules or tablets containing active substances. Functional food should be characterised by an enhanced availability of the active substance naturally contained in it or a special addition of such a substance, if it is not contained in a given food product. Functional food may also be obtained by the elimination of a component with a potential adverse health effect from a given foodstuff (Doyon and Labrecque 2008).

At present, the most important regulation regarding functional food in Europe is the Health Claims Regulation that was established in 2012 by the European Food Safety Authority (EFSA). The Regulation includes a list of more than 200 permitted health claims that has been published in the Official Journal of the EU (Commission Regulation EU No 432/2012). The health claims concern particular nutrients, substances, food or food categories. All marketing referring to possible health effects of specific foods is allowed after a recommendation by the EFSA. The authorised health claims for food may lead to an increased acceptance of functional products. Health claims are more convincing for many consumers than nutrition claims (Annunziata and Vecchio 2013).

CATEGORIES OF FUNCTIONAL FOODS

There are different criteria for the division of functional food. We may distinguish products enriched with or containing a reduced amount of a specific component. The most important bioactive substances added to food include polyunsaturated fatty acids, particularly omega-3, sterols, vitamins and minerals, dietary fibre, pro- and prebiotics as well as substances enhancing natural immunity. Thanks to the elimination of adverse components we obtain products with reduced contents of cholesterol, sodium or with lower calorie content. Improved foods are also called designer foods (Roberfroid 2002).

In terms of its specific use, functional food is divided into three groups. The first comprises products reducing the risk of disease development and having an augmenting effect in the treatment of such conditions as cardiovascular diseases, cancer, osteoporosis, diabetes, allergies, metabolic disorders and dyspepsia. The second group includes products supplying nutrients in situations of their increased requirement, i.e. for pregnant and lactating women, infants, intensively growing teenagers, athletes as well as the elderly or individuals suffering from stress. The third group comprises products enhancing the sensation of well being and the psychophysical efficiency of the organism (Hawkes 2004).

Most functional products exhibit a multifaceted effect on the human organism and may be included in several of the above-mentioned categories. Bioactive components contained in functional food improve cardiac performance and the functioning of the cardiovascular system. They also enhance the functioning of the alimentary system and promote the maintenance of adequate body weight. In many cases they also have an advantageous effect on the lipid metabolism of the organism and regulate the natural immunity as immunomodulators (Havrlentova et al. 2011).

VEGETABLES AS SOURCES OF BIOACTIVE SUBSTANCES

Vegetables in an everyday diet constitute natural sources of biologically active components that have an advantageous effect on the functioning of the human organism. They supply dietary fibre, vitamins and minerals, anthocyanins, carotenoids and substances with an anti-carcinogenic effect. Due to the content of these components, vegetables fulfil the criteria of functional food.

Dietary fibre plays a considerable role in the prevention of disease development, serving numerous functions in the human organism (Slavin 2005). It binds water, fatty acids and metals, reduces blood glucose and cholesterol levels, as well as increasing the rate of chyme passage through the intestines. Dietary fibre is divided into soluble and insoluble fractions, which exhibit different effects in the human alimentary tract (Bravi et al. 2009). The

ratio of both soluble and insoluble fibre in the diet is also crucial, with the optimal proportion ranging from 1:4 to 1:3. The primary sources of dietary fibre in everyday diet include cereal products, vegetables, fruits and the seeds of legumes. Vegetables supply 30-40% of total dietary fibre (Rodriguez et al. 2006). Research shows that among vegetables, carrots and cabbage are the main sources of dietary fibre in the typical diet of Poles, supplying 11.2 and 9.2% of dietary fibre, respectively (Wolańska 2011).

Anthocyanins are important food components, reducing the risk of cardiovascular diseases (Cooke et al. 2005). They are natural plant pigments classified as flavonoids, assuming a colour from red to purple depending on pH and added metal ions. Anthocyanins are found in many plants, including fruits and vegetables. Among vegetables, high anthocyanin contents are found in red cabbage and red onions (Wang and Stoner 2008). Anthocyanins exhibit a very wide spectrum of biological activity, including anti-inflammatory, antibiotic and anti-carcinogenic properties (Mazza 2007). Anthocyanins supplied in the diet reduce the risk of cardiovascular diseases and arterial hypertension (Bagchi et al. 2004). Anthocyanins exhibit antioxidant properties, which made them good protective agents against age-related diseases, neurological diseases and inflammation processes. Anthocyanins have also other beneficial health effects such as the improvement of visual acuity, anti-mutagenic properties, anti-diabetic effects and skin protection against UV-B radiation (Oancea and Oprean 2011).

Carotenoids constitute another group of plant pigments. Carrots are a rich source of these compounds, containing mainly α- and β-carotene in the A provitamin (Minguez-Mosquera et al. 2002). The content of β-carotene in carrot amounts to 6-11 mg%, which accounts for 45-70% total carotenoids. α-carotene constitutes another 20-40%, while other carotene pigments include γ-carotene, β-zeacarotene, lutein, licopene and phytofluene. Carotenoids serve an important role in the organism, preventing the oxidation of LDL cholesterol and as a consequence preventing atherosclerosis (Tapiero et al. 2004). Carotene pigments trap free radicals and active atomic oxygen in the organism, preventing oxidative stress (Stahl and Sies 2003).

Red beets are a source of water-soluble pigment known as betalains (Moreno et al. 2008). This group of pigments includes red-purple betacyanins and yellow betaxanthines (Kujala et al. 2000). Betacyanins comprise the major part of pigments in beets and among them betanin constitutes 75-95% (Mortensen 2006). The skin of beetroots also contains phenolic compounds such as coumaric and ferulic acids, which exhibit high antioxidant activity (Kujala et al. 2001). Betalains have been shown to be capable of inhibiting the development of skin and lung cancer cells (Stintzing and Carle 2004). The antiradical actions of betalains have also been demonstrated (Stintzing and Carle 2007).

VEGETABLES IN CANCER PREVENTION

Vegetables are also sources of other compounds that may prevent the development of cancers. The use of specific components of the diet in the prevention of cancers is referred to as chemoprevention. Vegetables from the family Brassicaceae are natural sources of chemo-preventive substances, such as isothiocyanates, which reduce the risk of lung, breast, colon and prostate cancers (Seow et al. 2002, Giovannucii et al. 2003, Ambrosone et al. 2004, Wang et al. 2004,). Sulforaphane is the best known representative of this group of compounds, with broccoli containing it in high amounts. The mechanism of sulforaphane's anti-carcinogenic properties is complex (Stierer et al. 2007). Sulforaphane exhibits an anti-carcinogenic efficiency at various stages of carcinogenesis. Research results indicate that the consumption of raw broccoli results in a three-fold higher concentration of isothiocyanates in urine than after the consumption of steamed broccoli (Conoway et al. 2000). The administration of sulforaphane in the case of healthy individuals or patients at risk of cancer seems to provide an attractive form of prevention, and the bioavailability of this compound in individual people may have a genetic background (Choi et al. 2007).

Tomatoes and their processed products, such as juice, concentrate or ketchup, are the primary sources of lycopene in the human diet (Rao and Rao 2007). The availability of lycopene is many times higher from processed products subjected to high temperatures than from fresh tomatoes. The bioavailability of lycopene is also enhanced in the presence of oil, since the pigment exhibits high lipophilicity (Wei and Giovannucii 2012). Many authors report that high consumption of lycopene reduces the risk of different types of cancers. The protective role of lycopene was shown in the case of hormone-dependent breast cancer (Cui et al. 2008) and prostate cancer (Wei and Giovannucii 2012) as

well as liver cancer (Yang et al. 2012). Lycopene exhibits strong antioxidant properties and may be applied in the prevention of cardiovascular diseases. The protective effect for the heart was observed at a daily lycopene dose of 20-40 mg (Jacob et al. 2008).

A wide range of health-promoting effects is ascribed to garlic, as well as other vegetables from the genus *Allium* such as onion, shallot, chives and leek. These vegetables are valued for their antibacterial, antifungal, antithrombotic and anti-atherogenic properties; they regulate blood pressure, reduce blood glucose levels and prevent arthritis (Rahman 2003). An increasing number of studies also indicate the effect of garlic consumption on the incidence of cancers (Khanum et al. 2004, Sengupta et al. 2004). Garlic reduces the risk of large intestine and colon as well as prostate cancers (Fleischauer and Arab 2001, Hsing et al. 2002). The anti-cancer effect is probably caused by organic sulphur compounds, of which total content is as high as 1% of the dry matter of garlic (Jones et al. 2004). This effect is enhanced by the presence of selenium and flavonoids in garlic, which influence the proliferation and growth of cancer cells, as well as arginine amino acid, which inhibits inflammatory processes, reducing the risk of certain cancers (Lind 2004, Neuhouser 2004).

HEALTH-PROMOTING PROPERTIES OF MUSHROOMS

Mushrooms, both cultivated and wild-growing, could be an important source of substances in the human diet augmenting the immune system and preventing cancer (Wasser and Akavia 2008, Wasser 2010). The fruiting bodies of individual mushroom species contain several active substances, including polysaccharides, triterpenoids, specific proteins and phenolic compounds. Several probiotic properties of mushrooms have been documented, including anti-cancer, immunostimulatory, antioxidant, antibacterial, antiviral and anti-diabetic properties; moreover, mushrooms exhibit a protective effect towards the cardiovascular system and the liver, and reduce blood cholesterol levels (Dai et al. 2009, Wasser 2011, Rathee et al. 2012). The most important mushroom species exhibiting medicinal properties include *Ganoderma lucidum*, *Lentinula edodes*, *Agaricus brasiliensis, Grifola frondosa*, *Coriolus versicolor* and *Cordyceps sinensis* (De Silva et al. 2012).

Studies on the effect of mushrooms on human health have been conducted at different research centres worldwide (Chen and Seviour 2007, Rop et al. 2009, Ferreira et al. 2010). Particular interest has been focused on the polysaccharides contained in mushrooms, first of all β-glucans, which are connected with their anti-cancer properties. The anti-cancer activity of β-glucans is found mainly in the (1→3)/(1→6)-β forms. The anti-cancer properties of β-glucans contained in mushrooms result not from their direct cytotoxic action, but rather the strong enhancement of the immune response of the organism (Wasser 2002, Enshasy 2010, Minato 2010). β-glucan activity has mainly been studied through testing on animals, and not many tests have been carried out on humans (Wasser 2011). The anti-cancer properties of lentinan have been proven in clinical practice in combination with conventional methods of cancer treatment such as chemotherapy and surgery (Zhang et al. 2011). In clinical trials, β-glucans linked with proteins showed stronger anti-tumour activity than free β-glucans (Jeurink et al. 2008).

β-glucans of fungal origin also exhibit antibacterial, antiviral and antiallergenic properties. These compounds are capable of reducing excessive cholesterol synthesis, high arterial pressure and blood glucose levels (Rop et al. 2009), and they also prevent diabetes (Perera and Li 2011). β-glucans obtained from mushrooms also exhibit strong antioxidant properties (Tsiapali et al. 2001). The most important β-glucans of fungal origin include lentinan isolated from the species *Lentinula edodes*, pleuran (*Pleurotus ostreatus*), schizophyllan (*Schizophyllum commune*), sclero-glucan (mushrooms from the genus *Sclerotium*) and grifolan (*Grifola frondosa*). Polysaccharide-protein complexes include Polysaccharide-K (Krestin), extracted from *Coriolus versicolor,* as well as ganoderan (*Ganoderma lucidum*) (Wasser 2011).

A highly important group of active substances contained in mushrooms comprises triterpenoids. Research has shown that they are active *in vitro* against several viruses: HIV1 and the herpes virus (Mothana et al. 2003). Other studies performed on animals confirmed the capacity of triterpenoids to inhibit cholesterol synthesis, to reduce blood pressure and platelet aggregation, thanks to which they reduce the risk of cardiovascular diseases (Berger et al. 2004). *Ganoderma lucidum* is a very rich source of these compounds, from which over 120 different terpenoids have been isolated, including ganoderic and ganoderemic acids and ganodermadiol (Liu et al. 2007). Triterpenoids from

G. lucidum directly inhibit the growth of cancer cells and reduce their invasive character (Sliva 2003).

Edible mushrooms are also considered to be potential prebiotics. Prebiotics are food components that are not digestible in the alimentary tract but have the capacity of stimulating the growth and activity of beneficial bacteria in the large intestine. This function is served by the carbohydrates contained in mushrooms, primarily chitin, hemicellulose, β- and α-glucans, mannans, xylanes and galactans (Aida et al. 2009). Extracts from *P. ostreatus* and *P. eryngii* were shown to stimulate the growth of probiotic bacteria, including *Lactobacillus* ssp., *Bifidobacterium* ssp. and *Enterococcus faecium* (Synytsya et al. 2008). Yamin et al (2012) confirmed that polysaccharides from *Ganoderma lucidum* supported the growth of *Bifidobacterium* ssp.

MUSHROOMS AS COMPONENTS OF FUNCTIONAL FOOD

To be classified as functional foods, mushrooms should have a beneficial effect on human health and be included in daily eating habits. Though the health-promoting properties of mushrooms have been shown in many studies (Guillamon et al. 2010, Chatterjee et al. 2011, Stachowiak and Reguła 2012), the benefits of eating mushrooms are little known by the population. Therefore, mushrooms are not part of the normal and usual diet of most people (Orsine et al. 2012). Currently there are many researchers working to spread the advantages of the consumption of mushrooms. The beneficial health effects can be obtained by eating mushrooms prepared in a variety of ways such as cooked, dried, smoked, salted or fermented (Candido and Fields 2005).

Studies on the addition of mushrooms to functional foods have also been conducted. Bassan et al. (2011) recorded a high level of acceptance of a gluten-free cake with the addition of *Agaricus brasiliensis* mushrooms. Investigations conducted by Lemos (2009) concerned a product similar to a burger based on the *A. brasiliensis* mushroom. A sensory analysis showed that the product was well accepted by consumers. Silva et al. (2009) demonstrated in a study that *A. blazei* mushroom extract added to soybean oil was effective in preserving the oil and could be considered a potential natural antioxidant. Miller et al. (2005) found that the addition of *A. brasiliensis* to tomato sauces led to an increase in the content of polyphenols in the sauces. In another study by Danyluk et al. (2006), sterilised meat products with mushroom powder were characterised by their high quality. Reguła and Siwulski (2007) reported that dried shiitake (*Lentinula edodes*) and oyster (*Pleurotus ostreatus*) mushrooms constituted a good source of microelements. The authors confirmed that extrudates with the addition of dried oyster mushrooms could be used as a food additive. Similarly, oyster mushroom (*Pleurotus pulmonarius*) powder was added to wheat flour utilised in bread production (Okafor et al. 2012). The results of the study showed that there was significant improvement in the bread protein content and nutritional quality with the addition of the mushroom powder.

Mushrooms may be consumed directly and treated as components of functional food. Their positive effect results from the interaction of different active components contained in their fruiting bodies. Moreover, ready-to-use fungal preparations in the form of capsules or tablets may be administered as a preventive measure or in the case of a diagnosed ailment. Such medicines contain purified fungal extracts and are treated as dietary supplements. They are used most frequently as preparations augmenting the immune system and preventing cancer (Wasser 2010). Preparations are produced first of all from the following species of medicinal mushrooms: *G. lucidum*, *L. edodes*, *G. frondosa*, *C. versicolor* and *C. sinensis*. Medications are also available containing extracts from different mushroom species (De Silva et al. 2012).

PROSPECTS FOR THE DEVELOPMENT OF THE FUNCTIONAL FOOD MARKET WORLDWIDE AND IN POLAND

The market for functional food is developing dynamically worldwide, including in poorer countries. It is estimated that in developed countries its growth rate is around a dozen percent annually. Japan and the USA constitute the largest market for functional food. It is believed that in the nearest future functional food may account for as much as 50% food products offered on the American market. In Japan and the USA, legal regulations are in force concerning this type of food, while in the European Union the legal status of this category of products is not completely regulated. In the USA and Japan beverages, cereal products and confectionaries predominate on the market for functional food, while in Europe dairy products account for approx. 50% and cereal products – approx. 30%, respectively (Menrad 2003).

The market for functional food is also developing in Poland. An increasing number of food producers have expanded their assortment to include functional products. In 2000 there were several hundred functional products on the Polish market, but they constituted only a slight percentage of all food products. At present the growth rate on the Polish market for functional food is approx. 3% annually, but it is markedly lower than in other European countries. While in Poland the turnover of functional food is estimated at €1.2 billion, in Great Britain it is approx. €5.7 billion (Kahl et al. 2012).

At the beginning of the twenty-first century a markedly greater number of people declared having knowledge about functional food in comparison to the number of people who actually consumed it (de Yong et al. 2003). At present consumer awareness on the benefits resulting from the consumption of functional food is systematically increasing. Approximately 40% of Europeans are of the opinion that the consumption of a specific type of food may be used as a method to improve health or to compensate for an unhealthy lifestyle (de Yong et al. 2003, Schryver and Smith 2006, Siro et al. 2008).

In Poland, consumer knowledge on functional food is still insufficient and may be a factor limiting the development of this branch of the food industry. According to the latest data, the percentage of Polish consumers who had heard of the concept of functional food increased from 4 to 9%, whereas 69% polled had not encountered this term. The most extensive knowledge on functional food was found among individuals with university education, urban dwellers, professionals and young people. It needs to be stressed that the declared lack of knowledge of the term functional food does not automatically mean that Poles do not purchase such products. Consumers choose functional products based on their intuition (Annunziata and Vecchio 2011).

In the opinion of many authors the key to the success of functional food lies in consumer awareness (Siro et al. 2008). Consumers need to have knowledge on the potential for health improvement thanks to the consumption of specific products. They should also be aware that they are buying an innovative product, for which it is worth paying an additional amount of money. Many problems, e.g. with the promotion of such products, are caused by a lack of a uniform and commonly accepted definition of functional food and respective legal regulations. At present the turnover of functional food in Poland is based on the general regulations of law on food products.

CONCLUSIONS

The ageing of societies, increased incidence rates of cancer, cardiovascular diseases, diabetes as well as the epidemic of obesity seem to promote the development of the market for functional food. Among functional food products an important position should be occupied by vegetables and mushrooms due to their contents of many bioactive components that have a beneficial effect on human health and sense of well being.

The effectiveness of functional food should be confirmed by health claims. New regulations in health claims for food can also help to increase the acceptability of functional products by consumers. On the contrary, the use of the term "functional food" only as a marketing catchphrase, as is often the case, may lead to the loss of credibility of such products. There is a question of whether functional food may be consumed in unlimited amounts and without consulting a physician. Many specialists voice objections that functional products may contain excessive amounts of active substances, causing their potential interactions. It is necessary to conduct further studies on the health safety of functional products.

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MOŻLIWOŚĆ WYKORZYSTANIA WARZYW I GRZYBÓW JAKO SKŁADNIKÓW ŻYWNOŚCI FUNKCJONALNEJ

Streszczenie: Znaczenie produktów funkcjonalnych na światowym rynku żywności systematycznie wzrasta. Wynika to ze zwiększającej się świadomości konsumentów, że można uzyskać poprawę stanu zdrowia poprzez właściwe odżywianie. Produkty funkcjonalne są adresowane do różnych grup odbiorców, posiadających zwiększone zapotrzebowanie na składniki odżywcze, lub przeznaczone do poprawy określonych funkcji organizmu. Rynek żywności funkcjonalnej rozwija się również w Polsce, lecz w znacznie wolniejszym tempie niż w innych krajach europejskich. Niewielka jest również wiedza polskich konsumentów na temat żywności funkcjonalnej. Wśród żywności funkcjonalnej ważne miejsce powinny zajmować warzywa i grzyby ze względu na zawartość wielu składników bioaktywnych mających korzystny wpływ na zdrowie i samopoczucie człowieka. Warzywa stanowią w codziennej diecie naturalne źródło błonnika pokarmowego, witamin, składników mineralnych, antocyjanów, karotenoidów oraz substancji o działaniu antyrakowym. Owocniki grzybów, zarówno uprawnych, jak i dziko rosnących, zawierają wiele substancji aktywnych, w tym polisacharydy, triterpenoidy, specyficzne białka oraz związki fenolowe. Pozytywny wpływ na zdrowie człowieka wynika ze współdziałania różnych składników bioaktywnych zawartych w owocnikach. Udokumentowano szereg działań prozdrowotnych

grzybów, między innymi przeciwnowotworowe, antyoksydacyjne, antybakteryjne, przeciwwirusowe i przeciwcukrzycowe. Konsumenci powinni posiadać szerszą wiedzę na temat możliwości poprawy zdrowia poprzez uwzględnienie warzyw oraz grzybów w codziennej diecie.

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