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Review

Pollen and bee bread as new health-oriented products: A review

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ABSTRACT

Background: An interest in substances of natural origin has been a subject that is increasing constantly-both those known for many years and recently discovered are of great interest to the researchers. This interest also applies to bee products because of their extensive nutritional and therapeutic properties; these products are known and used for several thousand years, but only recently, they became the subject of sparse documented scientific research. With the passing of time, it is difficult to determine what will be the wishes and requirements of the future consumers, what should be introduced to new technologies to ensure the demand for new products.
Scope and approach: Recently, there has been an increasing demand for natural products, particularly the bee products. Bee bread and pollen, due to their nutritional and medicinal properties, are used for apitherapeutic purposes. These include about 200 different substances, such as free amino acids and vitamins. Special attention should be attributed to unsaturated fatty acids such as linoleic, linolenic, and arachidonic, which are found in pollen and bee bread.
Key finding and conclusion: The fashion for a healthy lifestyle leads to a situation where a number of people start taking care of their health. They search for the highest quality products, preferably with health benefits, rich in vitamins, valuable bioelements, and nutrients. Therefore, bee bread that is rich in beneficial ingredients has proved to fulfill these expectations. It constitutes a wholesome, biologically active nutrient, which can be used in the food industry.

1. Introduction

The first traces demonstrating bee products' acquisition by humans came from the rock paintings discovered in 1919 in Spain in the Cave Spider (Cuevas de la Araña) located by the River Cazunta near Valencia. The painting shows a person taking honey from wild bees. It is assumed that the painting was created in the years 8000–5000 BC, that is, at the turn of middle and younger Stone Age (Neolithic Age) (Nayik et al., 2014). In many non-European countries, indigenous people still deal with the search for the nests of bees living in the wild to gain bee products.

The history of bee products dates to the ancient times. The Greeks believed that honey and pollen are the food of kings, giving the youth and life. The bee pollen is mentioned in the holy scriptures, including the Bible: "And God said, Behold, I give you every plant yielding the seed of the whole earth and every tree that which fruit has the seed, let they be your food" (Genesis). Hippocrates, Pliny the Elder, and Pythagoras believed that pollen shows therapeutic effect. Pollen began to be used on a larger scale for human consumption only after the Second World War, when the method of pollen traps was improved and easily accessible (Campos, Frigerio, Lopes, & Bogdanov, 2010). Bee products in ancient times were not only highly valued products, but played a major role in the religious rites of almost all cults.

The history of beekeeping on the Polish lands dates back more than two thousand years. The first record related to this activity comes from the Arab traveler Ibrahim ibn Yaqub, who in the 10th century wrote about Poland as a country abundant "in the food, meat, honey, and the arable lands" (Madras–Majewska & Majewski, 2007). The chronicler, Gallus, who arrived to Poland at the beginning of the 11th century, mentions the abundance of honey and forest beekeeping. Poland was commonly defined as "the land flowing with milk and honey." In view of the already made and continued civilization characterized by development, today beekeeping in Poland operates in economic, natural, and environmental conditions other than in the recent past. A significant technical progress has been made and is continued; there are new threats posing to the life of bees, and science is offering solutions and technologies that have been developed, which were unknown in the past (Pałach 2004). An important aspect is the reactivation of

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beekeeping, which provides wide opportunities. In the past, Poland was the only country in the European Union that made an attempt to restore beekeeping on its area, as the primary method of bee-rearing. This aims to create the image of Poland as a country that not only cultivates its history (beginnings of beekeeping, bee-rearing), but also tries to bring its past elements back to life (Śliwka & Staniszewski, 2013).

Today, the use of products of natural origin must have a perspective program of development and specified aims of its implementation. This is primarily the task for the scientists, who should timely notice the upcoming threats and crises, and thus affect the economy to ensure its rational development, availability of raw materials, and food security. The concept of sustainable development of bee products, which could become an alternative to the products already present in the market, is a very important issue. Modern trends concerning consumer's behavior and needs set the directions for the development of new products and thus new technology for their production. For example, an increase in the environmental awareness of the consumers constitutes the diversification of an activity of enterprises from many food industries to start the production of organic products. Health-promoting aspects of the food are significant in searching for a new offer to the consumers. Bee products, an example of which is the bee bread, are characterized by a wide range of biological properties (Fuenmayor et al., 2014).

2. Bee products

Biologically active substances of natural origin always focus a great interest. This also applies to bee products because of their powerful healing properties. Despite this, the fascination with these issues has not been diminished. On the contrary, even a deeper learning about the properties of these products creates new problems for scientists and practitioners, which remain difficult to explain. Bees' life is still the subject of scientific interest and a source of inspiration for artists, and the bees remain the symbol of diligence and thrift. The desire to use the valuable properties of bee products contributes to the development of apitherapy, specific area of treatment. Only over the last three decades, apitherapy has been the subject of documented scientific research. Expanding the knowledge of bee products and their use is associated with the improvement of apiary methods and an increasing number of people engaged in these issues.

Bee products are multicomponent natural substances necessary for the proper course of basic life reactions (Bobis et al., 2010). These include the following: honey, pollen, and extracts derived from it, that is, bee bread, propolis, royal jelly, and bee venom. Bee products demonstrate a wide range of healing effects. They increase the level of ATP, thus neutralize an effect of many toxic agents, increase immunity of an organism, and improve the energy balance of tissues. They participate in many stages of protein metabolism. They are involved in the synthesis of nucleic acids and are essential to the proper functioning of the circulatory system of living organisms.

3. Pollen

Pollen is often regarded as "the world's best food product" (Bobis et al., 2010). Global production of the pollen is around 1500 tons per year. The largest producers are China, Australia, and Argentina (Estevinho, Afonso, & Feás, 2011). Pollen is a product harvested by bees. The pollen transferred to the hive in the form of pollen loads is called the "bee pollen." It is the product that contains valuable substances such as essential amino acids, phenolic compounds, vitamins, pigments (chlorophyll, carotenoids), which can act as strong antioxidants. Numerous studies indicate (Lazaridou, Biliaderis, Bacandritsos, & Sabatini, 2004; Nayik et al., 2014) that the antioxidant activity of bee products is variable and generally depends on the type and source of flowers, geographical origin, climatic conditions, processing, and storage. Pollen consists of male reproductive cells of the seed plants, formed in flower thecae (Zuluaga, Serrato, & Quicazan, 2015). The nutritional value of pollen is often evaluated by the protein concentration, as well as the presence and quantity of essential amino acids (Roulston & Cane, 2000). Some pollen types are classified as highly nutritious, while others exhibit a marginal value.

Pollen from entomophilous plants is characterized by higher nutritional value compared to that from anemophilous ones. Pollen is the only source of protein that bees collect from the nature. This is very important for the development of the offspring, and thus for the development of bee colonies (Anđelković et al., 2012). In one day, the bee colony can collect from 50 to 250 g of pollen (Komosińska-Vassev et al., 2015). Bee family can collect from 15 to 40 kg of pollen per year (Zuluaga et al., 2015). Foraging bees carry the pollen to the hive in the form of pollen loads (lumps moistened with a little nectar or honey) in the recesses of the shins of hind legs called "the cages" (Barajas, Cortes-Rodriguez, & Rodríguez-Sandoval, 2012). The average weight of pollen carried by the bees is about 7.5 mg. Most pollen consists of a single grain, which is sometimes connected to two or more grains (Komosińska-Vassev et al., 2015). Pollen grains considerably differ in shape and size. In the dry state, these are mostly spherical or spindle-shaped formations, and after swelling, they may have round, triangular, cylindrical, bell-shaped thorn-like cross-section. Their diameter ranges from 0.01 to 0.05 mm (Barene, Daberte, & Siksna, 2015). The color of pollen loads is sometimes variable and reflects the diversity of plant species from which the pollen is obtained (Deveza et al., 2015). The color is usually in various shades of yellow, gray-white, orange, reddish, greenish, blue. Some differences in pollen color depend on whether it was collected from the already open thecae or they were cracked by the bee. The size and shape of pollen grains and its surface form are characteristic of particular plant species. From a practical point of view, pollen grains can be used to identify various plant species (de Arruda, Pereira, de Freitas, Barth, & de Almeida–Muradian, 2013). In order to collect the pollen load, the bees visit a different number of flowers; these visits depend on the kind of pollen, grain size, and the degree of viscosity. The pollen from anemophilous plants is light and dry. The size and shape of the pollen load is dependent on the visited plants. If it comes from anemophilous plants, it is mostly large and loosely arranged, while it is smaller and more compact from entomophilous plant. Certain types of pollen are not collected by bees; these may include linden pollen. This is probably related to the presence of large amounts of calcium oxalate. Some species of plants produce pollen of toxic properties, for example, aconite, false hellebores, some species of ranunculus, marsh marigold.

The next stage of pollen transport is the pollen being collected from the foraging bees to the hive and packed into honeycomb cells (Fig. 1) (Fuenmayor et al., 2014). When being packed into the cells, the pollen is further enriched by the bees with honey, as well as digestive enzymes and organic acids that are contained in the secretions of the salivary

Fig. 1. Beekeeping frame.

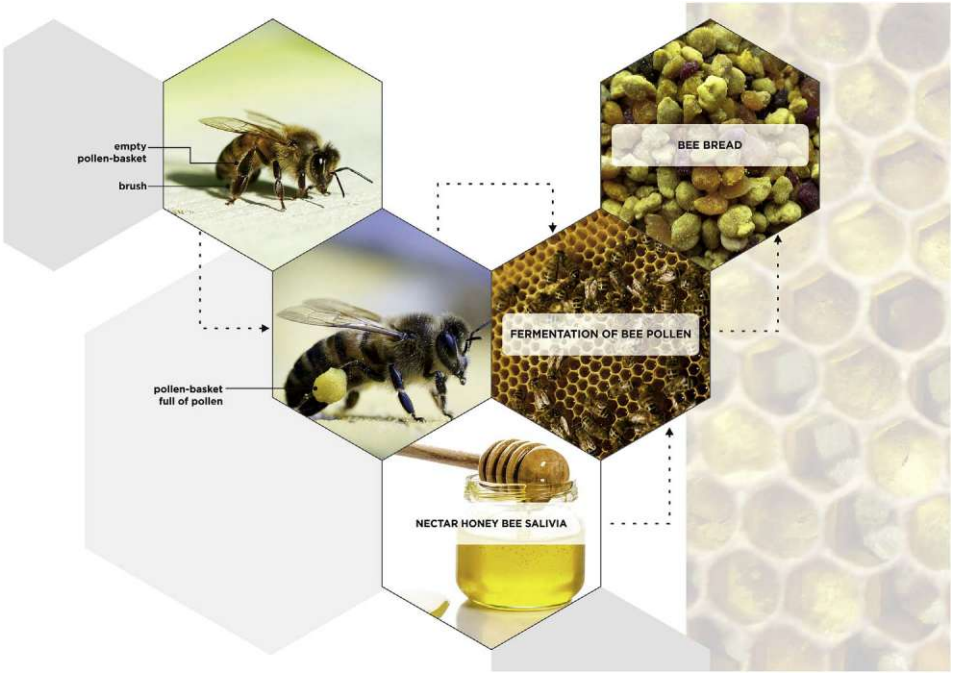

Fig. 2. The process of making a bee bread.

glands of bees (Deveza et al., 2015). The process of lactic fermentation of pollen caused by bacilli of *Lactobacillus* bacteria spontaneously occurs in the honeycombs, under anaerobic conditions. Pollen sheaths are dissolved just in the process of pollen transformation into the bee bread, and in this form, it becomes more readily absorbed. Fermentation to the form of bee bread not only protects the pollen against the loss of properties, but also gives rise to new components as a result of enzymatic transformations (Fig. 2). The pollen proteins are degraded to peptides and amino acids during the fermentation process. The study conducted by DeGrandi-Hoffman et al. (2013) showed that protein concentration in the pollen is higher than that in bee bread, while amino acid concentrations were lower in most cases. An elevated level of free amino acids may be the result of an activity of specific proteolytic enzymes that cause the breakdown of peptide bonds within the polypeptide chain. The concentration of certain amino acids (tryptophan) may be lower in bee bread compared to pollen. This phenomenon may be related to the reduction process, which is caused by microbial activity. Some microorganisms can use amino acids as a source of carbon and energy for their growth. Furthermore, free amino acids can also be incorporated into the structure of proteins, which, in turn, reduces their concentration. The content of these compounds in bee bread may be determined not only by the source of pollen, but also the genotype of bees performing the conversion to the bee bread (DeGrandi–Hoffman, Chen, & Simonds, 2013).

The concentration of lactic acid in bee bread is six-fold higher than in pollen (Nagai, Nagashima, Myoda, & Inoue, 2004). Bee bread obtained from birch pollen contained six-fold more lactic acid than the pollen grains derived from the same plant. The processes of pollen transformation to bee bread are accompanied by biochemical reactions. It is postulated that this is the result of microorganisms' activity, particularly lactic acid bacteria (Anđelković, Jevtić, Mladenović, Marković, Petrović & Nedić, 2012). The presence of lactic acid preserves the bee bread, which, in turn, affects the ability of longer storage of the resulting product.

4. Chemical composition of pollen

Fresh pollen loads contain water ranging from 21% to 30%. Such a high level of water content in the pollen favors the rapid growth of various microorganisms, which, in turn, results in its rapid deterioration. In the case of pollen subjected to drying, the moisture content ranges from 2% to 9%. Commercial pollen contains 5.91% of water (Bobis et al., 2010), while the data presented by de Arruda et al. (2013) showed 3.47% water content in the pollen coming from Pariquera-Açu, São Paulo, Brazil. Water activity of bee pollen that is ready for consumption is about 0.268 (0.261–0.280) (Gonzalez, Hinojo, Mateo, Medina, & Jiménez, 2005). Water content in the pollen is a very important factor determining the amounts of all other components in this product. Pollen containing less than 3% moisture is undesirable since it can lead to discoloration and undesirable chemical reactions (Maillard reaction, oxidation of lipids), resulting in a product with improper smell and taste (rancid) (Nogueira, Iglesias, Feás, & Estevinho, 2012; Serra Bonvehi & Escolà Jordà, 1997). The average ash content in the pollen is in the range from 1.5% to 3.2% (Human & Nicolson, 2006). The pH of the pollen is from 3.8 to 6.3 (Barene et al., 2015; Fuenmayor et al., 2014).

The presence of more than 250 substances with high biological activity was determined in the pollen from different plant species (Komosińska-Vassev et al., 2015). The discussed product contains proteins, carbohydrates, lipids, fatty acids, flavonoids, enzymes, vitamins, and micronutrients (Deveza et al., 2015). The pollen collected in the spring is significantly different in terms of amino acid content compared to the pollen load collected by bees in the summer. The content of carotenoids and vitamin C in pollen loads collected from various plants is clearly differentiated (Kędzia, 2008).

There are six nutrients necessary for human and animal functioning: three of them such as carbohydrates, fats, and proteins provide energy in the form of calories and the other three such as vitamins, minerals, and water do not deliver calories but are important for human health. All the examined bee products are characterized by high nutritional value, providing health benefits to humans. The high content of simple sugars, proteins, amino acids, and monounsaturated fatty acids may constitute an ideal natural supplement that provides energy, rebuilds the tissues, and strengthens the immune system of organisms (Bobis et al., 2010).

Pollen is by far the most important source of proteins and free amino acids (Table 1). The taste value of pollen is related to the content of protein. Bee pollen is characterized by very high protein content, but it varies greatly depending on the source plant, from 7% (pine) to 35% (date palm) (Paramás, Bárez, Marcos, García–Villanova, & Sánchez,

Table 1
Pollen and bee bread and human nutritional requirements.

Component	Bee Pollen	Bee Bread	RDI for 15 g[a]	References
Proteins	7-40%	14-37%	5-22%	Karmakar, 2015; Fuenmayor et al., 2014; DeGrandi-Hoffman et al., 2013; Zuluaga et al., 2015
Carbohydrates	24-60%	24-34%	1–4.6%	Nagai et al., 2004; Estevinho et al., 2011;, Barene et al., 2015
Lactic acid	0.56%	3.2%	–	Barene et al., 2015; Nagai et al., 2004
Lipids	1-18%	6-13%	0.1–4%	Campos et al., 2008; Nagai et al., 2004
Cellulose	3.7%	2.7%	–	Anđelković et al., 2012
Flavonoids	0.2–2.5%	nd	0.03%	Komosińska-Vassev et al., 2015; Serra Bonvehí et al., 2001
Vitamin	0.02–0.7%	nd	2-70%	Farag & El–Rayes, 2016
Nucleic acid	0.6–4.8%	nd	–	Karmakar, 2015; Kędzia, 2008
pH	3.8–6.3	4.3	–	Barene et al., 2015; Fuenmayor et al., 2014

nd no data.
[a] Campos et al., 2010; Required Daily Intake requirements are according to Reports of the Scientific Committee for Food, 2010. Average RDI values have been assumed.

2006). The content of this component in pollen derived from sunflower (*Helianthus annuus*) is only 15% (Anđelković, Jevtić, Mladenović, Marković, Petrović & Nedić, 2012; Bridgett, Kirk, & Drijfhout, 2015). In exceptional cases, it may be up to 40% (Campos, Cunha, & Markham, 1997;Campos et al., 2010; Fuenmayor et al., 2014; Karmakar, 2015). These results are similar to the data obtained by Szczęsna (2006) for pollen originating from Poland, Portugal (Estevinho, Rodrigues, Pereira, & Feás, 2012; Vaudo, Patch, Mortensen, Tooker, & Grozinger, 2016), and Brazil (Almeida–Muradian, Pamplona, Coimbra, & Barth, 2005). Protein content in pollen coming from Brazil and Argentina ranged from 23.5% to 27.7% and from 24.1% to 37.3%, respectively (Melo, Freitas, Barth, & Almeida–Muradian, 2009; Vit and Santiago, 2008). The content of organic nitrogen in Portuguese pollen ranged from 24% to 34% (Estevinho et al., 2012; Nogueira et al., 2012). The study presented by Bobis et al. (2010) demonstrated that "Royal Jelly" pollen contains protein ranging from 16% to 22%. According to Kędzia (2008), pollen protein contains the following fractions: albumins (35.4%), globulins (18.9%), glutelins (18.6%), prolamins (21.8%), and other proteins (including enzymes—5.3%). Proline is a major free amino acid in both honey and pollen and is present in amounts that may significantly exceed half of the total content of free amino acids (Paramás et al., 2006).

Vanderplanck et al.'s (2014) study results showed that the protein content in pollen loads differs significantly from pollen collected manually. This is probably related to the nectar addition to pollen by bees. Standifer, McCaughey, Dixon, Gilliam, and Loper (1980) demonstrated slight differences in protein content in pollen derived from common almond (*Prunus dulcis*) (22.6%) compared to that collected by hand (22.2%). Roulston, Cane, and Buchmann (2000) demonstrated a very large variation for protein content in pollen derived from Lombardy poplar (*Populus fremontii*) collected by bees (16%) compared to manual collecting (43.1%). This difference in protein content between pollen load and hand-collected pollen is often high, but very variable depending on the plant species (Vanderplanck, Leroy, Wathelet, Wattiez, & Michez, 2014).

The pollen also contains substantial amounts of nucleic acid (0.6–4.8%) (Karmakar, 2015; Kędzia, 2008). Nucleic acids play a big role in the transmission of hereditary traits and in the regulation of important processes of synthesis. The predominance of deoxyribonucleic acid (DNA) was found in the nuclei of pollen cells of a generative nature, while the predominance of ribonucleic acid (RNA) was found in the nuclei of pollen cells of a vegetative nature. Pollen also contains nucleoproteids such as simple proteins (histones, protamines, albumins, and globulins) associated with nucleic acids (Kędzia, 2008). The DNA present in pollen does not have metabolic recovery mechanism found in other diploid DNA cells. Therefore, the antioxidant compounds present in pollen can provide protection against solar radiation. Pine pollen can be damaged if exposed for 3–4 h for UV radiation coming from sunlight. The presence of a very large amount of ascorbic acid was found in the pine pollen (LeBlanc, B. W., Davis, O. K., Boue, S., DeLucca, A., & Deeby, 2009).

Carbohydrates constitute a major part of pollen, which are about two-thirds of their total dry weight (Estevinho et al., 2011). Carbohydrates absorbed by human organism are present in pollen in an amount ranging from 24% to 35% on average (Nagai et al., 2004). According to Estevinho et al. (2011), the content of carbohydrates in pollen coming from Portugal ranged from 60.8% to 70.7%. Monosaccharides account for about 94% of total sugars present in the pollen. The main sugars include fructose, glucose, as well as disaccharides like sucrose, turanose, maltose, trehalose, and erlose (Bobis et al., 2010). The ratio of glucose to fructose in pollen from Colombia was from 1.20 to 1.61 (Fuenmayor et al., 2014). The total carbohydrates content in the pollen can be subject to considerable variations depending on the plant from which the bees collect the pollen, as well as the country of pollen origin. Cellulose content in the pollen is in the level of about 3.72% (Anđelković, Jevtić, Mladenović, Marković, Petrović & Nedić, 2012). This unbranched polysaccharide is the primary constituent of pollen grain sheaths. The outer layer, called the exine, is very durable and is composed of sporopollenin; it can be smooth or equipped with all sorts of appendages, spines with complex geometries. It provides the protection of bioactive compounds and chemical resistance. The inner layer is called "intin" (Barene et al., 2015; Zuluaga et al., 2015). It is composed of cellulose and is structurally similar to the plant cell wall (Xu, Sun, Dong, & Zhang, 2009). Not all carbohydrates found in pollen are valuable nutrients. The important part of pollen carbohydrates is pectin, but its nutritional value has not been documented (Bobis et al., 2010).

The total lipid content in pollen is very diverse, ranging from 1% to 13% (Campos et al., 2008; Nagai et al., 2004). It is highly variable and depends on the content of fatty acids, carotenoids, and vitamins. First of all, the lipids present in pollen include the following essential fatty acids: linoleic acid, γ-linolenic acid, and arachidonic acid (Komosińska-Vassev et al., 2015). Seppänen, Laakso, Wójcicki, and Samochowiec (1989) found the content of six fatty acids in the pollen. Saturated fatty acids included the following: myristic acid, stearic acid, and palmitic acid. Unsaturated acids were represented by oleic acid (1.5%), linoleic acid (5.4%), and α-linolenic acid (65.7%) (Campos et al., 1997). The sum of the content of unsaturated and saturated fatty acids amounted to 61.9% and 38.1%, respectively (Seppänen et al., 1989). The absorption of cholesterol in the intestines is affected by β-sitosterol present in the bee bread and bee pollen. While the triterpene compounds such as oleanolic acid and ursolic acid-β prevent the formation of tumor diseases (Anna Rzepecka-Stojko et al., 2012). Unsaturated acids form readily soluble complexes with cholesterol and, therefore, contribute to its reduced concentration in the blood, preventing the development of atherosclerosis (Paradowska, Zielińska, & Krawiec, 2014). The presence of *cis*-8,11,14-eicosatrienoic, tricosanoic, and lauric acids was noted for pollen coming from Cundiboyacense region (Colombia) (Fuenmayor et al., 2014). Phospholipids and plant sterols (β-sitosterol) are represented in smaller amounts in the pollen, that is, 1.5% and 1.1%,

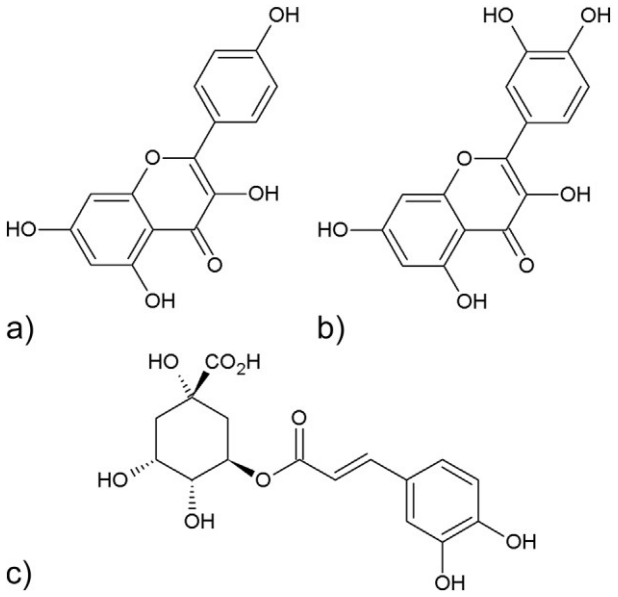

Fig. 3. The chemical structure of flavonoids most commonly found in pollen and bee bread.
Kaempferol (A)
Quercetina (B)
Chlorogenic acid (C).

respectively (Komosinska–Vassev, Olczyk, Kaźmierczak, Mencner, & Olczyk, 2015).

Pollen is rich in polyphenolic compounds, mainly flavonoids and phenolic acids. The content of flavonoids is in the range of 0.2–2.5% (mainly flavonols, rutin, catechin, myricetin, leukotrienes, and phenolic acids). The flavonoids present in pollen (1.4%) (Fig. 3) mainly include kaempferol, quercetin, and isorhamnetin. In case of phenolic acids (0.2%), we can distinguish chlorogenic acid (Komosińska-Vassev et al., 2015; Serra Bonvehí, Soliva Torrentó, & Centelles Lorente, 2001). According to Pascoal, Rodrigues, Teixeira, Feás, and Estevinho (2014), the content of flavonoids in pollen ranges from 3.7 to 10.1 mg/g. The pollen also contains small amounts of leucoanthocyanin, that is, derivatives of catechin (Paradowska et al., 2014; Rzepecka–Stojko, Stec, Kurzeja, Gawrońska, & Pawłowska–Góral, 2012). These values can vary considerably depending on the origin of pollen. These compounds are mainly found in combination with molecules of sugars in glycoside form. Phenolic compounds are responsible for the color of grain (yellow, brown, red, purple, etc.); their characteristic feature is the bitter taste (Zuluaga et al., 2016). Due to flavonoid content, pollen demonstrates the activity of sealing and strengthening blood vessels, thereby improving blood circulation and heart function. Bee pollen—-like other bee products (honey, bee bread, and propolis), due to the high content of phenolic antioxidants and flavonoids—is characterized by high antioxidant activity, which, in turn, results in pollen's capability of removing free radicals and protecting an organism from the adverse effects of reactive oxygen species (Paradowska et al., 2014). The combination of these compounds with a high content of B vitamins may be beneficial for an organism (de Arruda et al., 2013).

Vitamins include a varied group of organic compounds that are necessary for the proper health and growth of all organisms. They demonstrate different biological functions and chemical compositions. Vitamins are involved in the synthesis of essential cofactors and a number of chemical reactions, which are regulated by metabolic enzymes and co-enzymes (de Arruda et al., 2013). Due to the presence of almost all vitamins in the pollen (about 0.02–0.7%), it is called the “vitamin bomb” (Farag & El–Rayes, 2016). We can distinguish fat-soluble vitamins (0.1%), which include A, E, D, and water-soluble vitamins (0.3%), an example of which are the B vitamins; vitamin C;

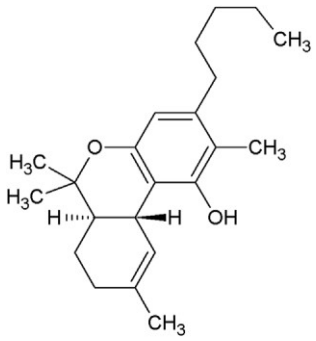

Fig. 4. Tetrahydrocannabinol.

pantothenic, nicotinic, and folic acids; biotin, rutin, and inositol (de Arruda et al., 2013). Depending on the season of the year, the content of particular vitamins varies between different species of pollen (Farag & El–Rayes, 2016; Al–Salem, Bhat, Al–Ayadhi & El–Ansary, 2016). Water-soluble vitamins are involved in the metabolism of fats, carbohydrates, and proteins. The content of these compounds naturally present in pollen and bee bread is difficult to estimate due to their concentrations, the presence of many disturbing factors, or the complexity of the matrix. In addition to improving the processes of extraction and purification, the biggest challenge in determining the content of vitamins in food includes the development and validation of the methods, which, in turn, may significantly affect the reduction of analysis time (de Arruda et al., 2013).

The pollen obtained from *Cannabis sativa* contained 16 compounds belonging to cannabinoids. This is a group of compounds with similar chemical structure and diverse pharmacological activity; for example, Δ^9-tetrahydrocannabinol shows hallucinogenic properties, while cannabichromene exhibits calming effect on the central nervous system (Fig. 4) (Ross et al., 2005). The authors do not specify what amounts of cannabinoids were present in pollen derived from *C. sativa*, but the pool of these compounds contained the highest amount of Δ^9-tetrahydrocannabinol (81%) and less cannabichromene (8.3%), cannabinol (3.6%), and cannabigerol (3.4%) (Kędzia, 2008).

Moreover, pollen contains over 25 different micro- and macroelements such as iron, calcium, phosphorus, potassium, copper, zinc, selenium, and magnesium. The presence of adequate levels of macro- and microelements in human organism is very important for the proper course of many different metabolic processes. Mineral components are necessary for proper regulation of metabolic pathways and physiological processes (Sattler et al., 2016). Their adequate intake is essential for the maintenance of homeostasis, cell protection, functionality, and health. For example, the combination of calcium, phosphorus, and magnesium is actively involved in the construction of bone tissue, maintaining a certain osmotic pressure of blood as well as cellular and intercellular fluids. The compounds of iron, copper, zinc, cobalt, and manganese play an important role in blood formation and also in the growth, development, and reproduction. Therefore, the deficiency of bioelements in an organism leads to many metabolic disorders and can cause severe developmental abnormalities and may even contribute to the formation of harmful diseases (Kędzia & Hołderna–Kędzia, 2005; Loper, Standifer, Thompson, & Gilliam, 1980; Gilliam, 1979a).

5. Bee bread

An increasing number of people appreciate the therapeutic effect not only of honey, but also of other products with wide application in apitherapy. Bee bread (ambrosia) is a unique product, which is very important not only for humans, but also for the bees. It is not always easy to get it, and the price is several times higher than the price of honey. The bee bread mainly includes pollen, honey, and secretions of bees’ salivary glands (Barajas et al., 2012; Vásquez & Olofsson, 2009).

Fig. 5. Bee bread.

Bees pack the components in the cells of the honeycomb, then secure the mixture with wax and honey (Barene et al., 2015). Such gathered and preserved pollen is subject to lactic fermentation in the environment of bee nest. Fermented bee pollen is called the "bee bread" (Fig. 5) (Fuenmayor et al., 2014; DeGrandi–Hoffman, Chen, & Simonds, 2013).

Bee bread is characterized by a higher nutritional value than pollen, better digestibility, and richer chemical composition (Habryka, Kruczek, & Drygas, 2016). Moreover, it is better absorbed by the human body than pollen since the components of bee bread are partially fermented and are more easily assimilated in an organism (Barene et al., 2015). Bee bread contains considerably larger amounts of peptides and free amino acids. Because of the proportions of particular components, the bee bread is an excellent food product that could supplement the deficiency of vitamins and nutrients in human organism. It acts in different directions to strengthen an organism and restore its proper functioning. Because of the presence of all the essential amino acids, bee bread is characterized by better composition than many valuable products obtained based on animal proteins. Bee bread also has good properties that help eliminate various toxins from organism (Habryka et al., 2016; Nagai, Nagashima, Suzuki, & Inoue, 2005).

According to the other sources (Gilliam, 1979a), the composition of bee bread is biochemically similar to the composition of pollen from which it is produced. However, it is not the same because of the enzymes contained in the bee bread and the lack of pollen sheath, which may disturb the absorption of nutrients contained in it. Bee bread contains about 30% protein on average (Degrandi-Hoffman et al., 2016). Bee bread is different from fresh pollen, and it contains more sugars and much less starch. According to Roulston and Cane (2000), the content of starch in pollen is in the range of 0–22%. Most kinds of pollen contain less than 5% of starch, and pollen derived from sunflower contains only 0.4% starch. Bee bread is rich in B vitamins, as well as vitamin K, which is not present in the fresh pollen (Gilliam, 1979a). The content of carotenoids in bee pollen derived from Latvia ranged from 6.7 to 9.3 mg/100 g. The content of lactic acid, which is a preservative agent, in bee bread is higher than 3%. The content of lactic acid in bee bread coming from birch pollen is six-fold higher than in the pollen. Carbohydrates constitute between 24 and 34% (Barene et al., 2015). Bee bread is more biologically active and easily digestible due to the high content of easily digestible sugars, fat, mineral components, and a higher proportion of free amino acids when compared to pollen (Nagai et al., 2004; Trzybiński, 2005). Bee bread may be a beneficial food product for people working mentally (Nagai et al., 2004). Any negative changes in nutritional habits between the bee bread and pollen were demonstrated. Currently, the scientific research conducted proved that the bee products played a huge role in detoxification process stimulation. Under their influence, harmful substances accumulated in an organism are converted to water-soluble compounds that can be easily removed from an organism (Estevinho, Pereira, Moreira, Dias, & Pereira, 2008; Almeida–Muradian, Pamplona, Coimbra, & Barth, 2005).

6. Microbiological quality of pollen and bee bread

Bee pollen is the result of a combination of various grains connected with nectar, bees' saliva, and honey. The consumption of this product is driven by constantly increasing demand for natural products characterized by health-oriented or therapeutic properties for an organism (Barreto, Funari, & de Oliveira Orsi, 2005). In addition, there are growing concerns about the sanitary quality of the food. Particular stages in the chain of beekeeping should be constantly monitored and good production and processing practice be implemented by the beekeepers to meet the demand for bee pollen and prevent harmful effects to the health of consumers (De-Melo, Estevinho, & Almeida-Muradian, 2015). An important issue concerning the criterion of pollen quality is its purity and microbiological safety. It should be emphasized that the deterioration of the quality of the product may result from negligence of beekeepers in the range of hygienic standards and proper handling of the product in the early stages of production. Such activities can lead to the product becoming harmful to the health (Deveza et al., 2015). It seems that the most critical step is pollen collection from the traps. The long-term pollen storage in the traps can cause an increase in humidity, which favors the growth of microorganisms. Bee bread poured with honey and blinded in honeycomb cells is well stored for a long time. However, when it is not blinded by the bees, it readily absorbs water vapor from the air, which could result in mold. The quality of the final product also depends on the process of cleaning, drying, packaging and the time of pollen or bee bread storage (Gonzalez et al., 2005).

Only a few countries have established microbiological criteria for dried pollen market turnover. Switzerland, Argentina, and Brazil are the first countries that implemented official regulations concerning the quality, physico-chemical properties, hygiene and sanitation of pollen (Estevinho et al., 2011). However, there is no specific international agreement regarding the rules concerning the quality bee products (De-Melo et al., 2015). In order to take advantage of the beneficial dietary and therapeutic properties of pollen, its quality must be monitored and rigorously respected (Estevinho et al., 2011).

Pollen is without any doubt the most valuable nutritional herbal product. Compared to other bee products, it is the least contaminated. The main pollution identified in pollen are heavy metals (Leita, Muhlbachova, Cesco, Barbattini, & Mondini, 1996; Conti Botre, 2001) and pesticides (Fleche, Clement, Zeggane, & Faucon, 1997; Kubik et al., 1999). Pollution from agricultural and industrial sources, for example, an uncontrolled use of pesticides, fertilizers, and other chemicals in crops, can lead to increased levels of heavy metals in agricultural ecosystems. The study conducted on the dehydrated and granulated bee pollen coming from the southeastern regions of Brazil demonstrated that pollen is sensitive to environmental pollution. Researchers suggest that it can be used as a bioindicator of pollution (Sattler et al., 2016).

It can be concluded from the report presented by Greenpeace (2015) that more than two-thirds of pollen transported to the hive by foraging bees in Europe is even contaminated with pesticides, which are composed, in extreme cases, of 17 different substances. David et al. (2016) demonstrated the presence of neonicotinoids and mixtures of fungicides in rape pollen. Fluvalinate and chlorfenvinphos were the most frequently detected pesticides in samples of pollen coming from Spain (Bernal et al., 2010). For optimum quality, the pollen should be stored in areas that are at least about 3 km away from the various sources of pollution (heavy traffic or agricultural areas treated with pesticides). The requirements concerning heavy metal content in pollen should be no more than as the following: Cd, 0.1 mg/kg; Pb, 0.5 mg/kg; As, 0.5 mg/kg; Hg, 0.03 mg/kg.

Bee pollen, which is aimed for the use only for people, should meet the relevant hygienic requirements and cleanliness of its acquisition. This is a very rigorous process. Therefore, the use of so-called upper

pollen traps is increasingly common, which provide an acquisition of the purest, least contaminated product (Internet, 2009). Thus, the obtained pollen has to be sifted through a fine sieve and carefully dried. The collection of pollen should not take place during wet weather.

Improper storage of the pollen (increased humidity) can cause the development of mold and bacteria. Therefore, prolonged durability can be attained by the proper selection of the drying process of bee pollen. In some parts of the world, the pollen is still dried naturally in the sun. When the temperature is too low, this may cause an increase in microbiological contamination (fungi growth), which, in turn, leads to the production of mycotoxins, causing acute or chronic poisoning in humans and animals (Estevinho et al., 2011; Gonzalez et al., 2005; de Arruda et al., 2013). Hot air drying is the best process often used in commercial production because of the better sanitary conditions and possibility to control the drying process conditions (Crapiste & Rotstein, 1997).

Due to the high protein content in pollen, its improper storage can lead to the deterioration in nutritional value due to the Maillard reaction (chemical reaction between amino acids and reducing sugars), loss of volatile compounds, or the appearance of undesirable odors as a result of lipid oxidation. Therefore, it is necessary to carry out the control and supervision of the process of product preparation and storage (Nogueira et al., 2012).

According to DeGrandi-Hoffman et al., (2013), pollen and bee bread contain bactericidal compounds, as well as carbohydrates and lactic acid, that are effective in reducing the growth of microorganisms, which include mold and spoilage bacteria. *Lactobacillus* and *Bifidobacterium* inhibit the growth of *Clostridium difficile, Staphylococcus aureus, Listeria monocytogenes*, some strains of Gram-negative bacteria like *Escherichia coli, Campylobacter jejuni*, rods of *Salmonella, Shigella, Vibrio, Klebsiella* types, and the yeast *Candida albicans*. Lowering the pH value during pollen conversion to bee bread is attributed to the activity of lactic acid bacteria that are introduced into the pollen from the gastrointestinal tract of the bees.

Raw pollen contains $5.0{\cdot}10^5$ cfu/g of aerobic mesophilic microorganisms and about $1.0{\cdot}10^2$ cfu/g yeast and mold (Bobis et al., 2010). De-Melo et al.'s (2015) study demonstrated the presence of mesophilic bacteria at a level of < 10 to $1.1{\cdot}10^4$ cfu/g in the dried bee pollen coming from Brazil. Psychrophilic bacteria constituted from < 10 to $1.1{\cdot}10^3$ cfu/g, bacilli from < 10 to $2.8{\cdot}10^3$ cfu/g, while the number of yeasts and molds ranged from < 10 to $7.6{\cdot}10^3$ cfu/g. The *Candida* genus predominates among the identified yeast. The presence of *Zygosaccharomyces rouxii* yeast was found in commercial samples of dried bee pollen coming from Portugal and Spain (Nogueira et al., 2012). Deveza et al. (2015) showed the presence of *Aspergillus* and *Cladosporium*, which were among the most common molds in the Brazilian bee pollen.

Scientists from the International Honey Commission (IHC), the aim of which was to propose quality criteria and international standards of pollen quality, recommend the limits for the number of aerobic microorganisms (< 10 cfu/g), yeast and mold ($< 5{\cdot}10^4$ cfu/g), Enterobacteriaceae (max $1{\cdot}10^2$ cfu/g), *E. coli* (absent in 1 g), *Salmonella* spp. (absent in 10 g), and *Staphylococcus aureus* (absent in 1 g) (Campos et al., 2008; De-Melo et al., 2015).

Lactic acid bacteria (LAB) isolated from the digestive system of honey bees (*A. mellifera*) inhibit the growth of *Paenibacillus larvae* pathogen, which is the cause of infectious bacterial disease of brood-American foulbrood (Vásquez et al., 2012). The lack of growth of pathogenic microorganisms that is observed in bee bread may be the result of accumulation of various metabolites of fermentation process carried out by lactic acid bacteria. These metabolites lower the pH of the environment and concurrently reduce the number of microorganisms (Vásquez & Olofsson, 2009). A group of microorganisms remaining in the final products are Gram-positive aerobic bacilli and certain molds, which, in these unfavorable environmental conditions, may progress to a latent life form (Audisio, Terzolo, & Apella, 2005). Certain strains of lactic acid bacteria produce hydrogen peroxide in concentrations inhibiting the growth of many pathogenic strains (Bang, Buntting, & Molan, 2003).

The dominant group of microorganisms after pollen fermentation includes fungi and spores of *Bacillus* spp. (Gilliam, 1979a, b). Developing fungi have the ability to decompose the pollen, potentially changing its nutritional value (Gilliam, 1997a). However, bacteria and fungi isolated from pollen have the ability to produce enzymes, vitamins, antibacterial substances, organic acids, lipids, which can contribute to the transformation and stabilization of pollen (Anderson et al., 2014).

Bee bread and pollen inhibit the growth of a broad group of microorganisms resistant to antibiotics. This activity was higher for Gram-positive than Gram-negative bacteria. Carpes et al.'s (2007) results showed that 80% ethanol extracts of the pollen inhibited the growth of *Pseudomonas aeruginosa*. In the case of *Staphylococcus aureus*, the inhibitory effect was already noted for 50% ethanol extract. Fatrcová–Šramková, Nôžková, Máriássyová, & Kačániová (2016) study demonstrated that the prepared dry extracts of sunflower pollen exhibited an inhibitory effect to bacteria *Paenibacillus larvae*, syn. *Bacillus larvae*, *Pseudomonas aeruginosa,* and *Enterococcus raffinosus*. The highest antifungal activity (*Aspergillus ochraceus* and *Aspergillus niger*) was found for the freeze-dried and frozen pollen extract derived from sunflower.

In the case of the use of extracts from poppy pollen (Slovakia), the most sensitive was *Staphylococcus aureus* (70% ethanol extract). For pollen derived from rapeseed and sunflower, the most sensitive microorganism was *Salmonella* Enterica (Fatrcová–Šramková et al., 2013). Antifungal and antibacterial activity was also demonstrated for Greek pollen. The antimicrobial activity may be due to a high content of quercetin and kaempferol in the examined pollen extracts (Graikou et al., 2011).

Kedzia & Hołderna-Kędzia's (2005) studies demonstrated that microbial decontamination of pollen using the ionizing energy allows to obtain a product of high microbiological purity. The resulting product is characterized by a virtually unchanged antibiotic activity. This proves that pollen maintained its therapeutic value.

The quality of food is an important element affecting consumers' behavior. The development of new technologies in food production, its storage conditions, is the basis for global market evolution. The systems for the supervision of production practices should be developed so that the produced food would be, by assumption, free of hazards. Such guarantee is provided by a constant monitoring of consumer protection against the microbiological, chemical, and physical risk, which can occur at all stages of pollen production.

7. Lactic acid bacteria in bee pollen

Growing importance of lactic acid bacteria results from the fact that they have the status of bacteria safe for humans and animals (GRAS—Generally Recognized As Safe). All lactic acid bacteria have a typical fermentation metabolism and gain energy as a result of transformation of saccharides present in the environment. The products of metabolism are organic acids, diacetyl, acetoin, acetaldehyde, and bacteriocins (Forsgren, Olofsson, Vásquez, & Fries, 2010; Waśko, Kieliszek & Targośnki, 2012). Rapidly developing studies in recent years demonstrated that produced metabolites significantly contribute to the inhibition in the development of pathogenic and toxin-forming microorganisms.

Lactobacillus and *Bifidobacterium* are the most important representatives of lactic acid bacteria, finding a widespread use as probiotics for humans and animals. *Lactobacillus* and *Bifidobacterium* bacteria were isolated from the digestive tract of honeybee *A. mellifera*, pollen, and bee bread. *Lactobacillus* were the dominant microflora present in honey (90.9% of all bacteria), pollen (74.6%), bee bread (83.9%), and royal jelly (93.3%) (Asama et al., 2015). Conducted phylogenetic analyzes showed that lactic acid bacteria flora consists of

twelve different phenotypes (Forsgren et al., 2010). Bacteria isolated from bee products (honey, pollen, and bee bread) demonstrated that the dominant species was *Lactobacillus kunkeei* (Endo & Salminen, 2013).

Huang et al.'s (2013) study demonstrated that the addition of *Lactobacillus plantarum* to food products reduces cholesterol level in blood serum. There are also grounds to believe that the rods of the genera *Lactobacillus* and *Bifidobacterium* may also have anticancer effects, reducing the effect of lactose intolerance (Almeida, Lorena, Pavan, Akasaka, & Mesquita, 2012). On the basis of their study, O'Sullivan, Thornton, O'Sullivan, Collins, (1992) found that lactic acid bacteria also demonstrate a significant antiallergic activity. The ability of lactic acid bacteria for the synthesis of these metabolites and their number largely depend not only on the species, but also on the strain and external factors, such as chemical composition of the medium, pH of the environment, temperature, and time of incubation. Lactic acid bacteria able to produce lactic acid synthesize it in three forms L(+), D(−), and LD. The ability to produce the acid in D(−) and L(+) forms by lactic acid bacteria can be adjusted by changing the environmental conditions during its biosynthesis and changing the composition of the culture medium. According to Vaccari et al. (1993), the initial glucose content of the medium significantly affects the efficiency and productivity of L (+) lactic acid. A huge metabolic differentiation of lactic acid bacteria contributes to the constant increase in the production of new, biologically stabilized food products with different organoleptic qualities. The highest number of so-called third-generation products may be found in the dairy industry.

For centuries, the man unknowingly used lactic acid bacteria in fermentation processes of sourdough bread, plant silage, cheese curd and ripened cheese, fermented milk, meat, meat products, fish, legumes production, etc. The vaccines or properly composed starter cultures composed of selected strains of lactic acid bacteria have been consciously used for years. Such starters are used in, for example, dairy as well as fruit and vegetable industries. Attention should be paid to the possibility of these microorganisms used in the production of bee bread in laboratory conditions.

8. Bee bread acquisition

Bees collect the pollen from flowers in order to meet their nutritional requirements; this is the only external source of protein for the colony. The principle of all the trap operation is the same, and it involves the blocking of the entrance to the hive with a special barrier with holes, through which the bees must crowd (Barajas et al., 2012). When passing through it, pollen loads are knocked off the legs of bees and fall into the tray of the trap. Pollen loads are collected by placing the pollen traps, thus the bees returning to the hive must crowd through the holes in the plate, leaving most of the pollen outside. After entering the hive, forager bee observes that it has already got rid of the pollen, and as a result, it goes for another set with even greater fervor (Fuenmayor et al., 2014). The yield of the collected pollen depends on the container, moisture, climate, and the size of the hive (Barajas et al., 2012).

Natural acquisition of bee bread in large quantities is difficult for technical reasons. It involves its extraction from the honeycombs. It is strongly compacted by bees and has the consistency of dry, hard balls, firmly embedded in the cells of the honeycomb. Its acquisition is hampered by the shirts from bee larvae cocoons, which rough surface makes it difficult to collect them. There are different ways to accelerate the acquisition of bee bread by grinding part of the honeycombs where the larger quantities of bee bread are accumulated. When the bee bread is aimed to be used as a medicinal, cosmetic, and nourishing product for humans, then it becomes necessary to collect bee bread by hand since it is the only way that assures the highest microbiological purity. Therefore, nutritional formulas of pollen or artificially prepared bee bread are prepared (Fuenmayor et al., 2014).

Misiewicz, Kieliszek, & Czarniak (2013) presented the method of bee bread preparation *in vitro* using wort and pollen combined with the strains of *Lactobacillus delbrueckii*. The process of bee bread preparation lasted for 14 days under anaerobic conditions. In the produced bee bread, lactic acid content was about 3%.

Acquisition of pollen can be carried out throughout the season. The bee colonies from which the pollen is obtained do not experience its scarcity since the bees are likely to work harder. The collection of pollen loads should be done as often as possible, in order to prevent pollen moisture, because pollen attacked by molds is not suitable for consumption. Particularly dangerous are the wet periods. The dried pollen loads must be cleaned of wax. Pollen can be cleaned by hand; however, the more effective is the use of mechanical devices (Habryka, 2016).

9. Biological properties of pollen and bee bread

The development of civilization results in the emergence of new lifestyles and thus innovative food trends. The way of feeding is shaped by socioeconomic conditions, family environment, regional customs, as well as nutritional messages. Human life is related to eating and assimilation of food. Table 1 shows the Daily Intake of nutrients found in the bee bread and bee pollen. The condition of proper human nutrition is the total coverage of their energy needs and all the nutrients needed for physical and mental development and health. Bee products can be supplements to normal human diet. The diet should provide all nutrients in amounts that meet standards, established and recommended based on generally accepted scientific data.

Pollen and bee bread are little known, completely underestimated bee products. They contain a wide range of ingredients; therefore, they are food with good nutritive value, controlling the activity of many internal organs (Bobis et al., 2010). Bee products accelerate the reconstruction of all cells in an organism improving the physical as well as mental state. They prevent the formation of a number of diseases that result from the lack of nutrients. Moreover, they are an antidote to various toxic substances produced in an organism; they demonstrate antibacterial activity and reduce the side effects of the antibiotic treatment (Nagai et al., 2004). Bee bread is a valuable food and health-oriented product. One of the advantages of bee bread is virtually unlimited stability in the storage process compared to the pollen subjected to drying or freezing (Bobis et al., 2010). The activity of pollen (content of vitamins and enzymes) is deteriorated after two or three months of storage (Barene et al., 2015).

The Federal Ministry of Health in Germany officially recognized the bee pollen as a drug (Linskens & Jorde, 1997). Pollen acts as an intestinal regulator favoring the processes of digestion and absorption of nutrients (Villanueva, Marquina, Serrano, & Abellán, 2002). Pollen increases immunity against harmful physical, chemical, and biological agents; this includes both increased physical fitness of the organism in case of excessive exercise load and the effect in improving brain functions. In fact, some nutritionists claim that people can actually live eating just bee pollen (Nogueira et al., 2012).

Nutritional properties of pollen, as well as regulation of metabolic processes, are used, inter alia, in the lack of appetite, delayed development, and malnutrition in children and adults (Nogueira et al., 2012). Patients with infections of the upper respiratory tract are allowed to systematically consume pollen for more rapid recovery. During severe and debilitating diseases, such as leukemia, pneumonia, it is also desirable to provide the pollen as an immunostimulatory agent (increasing organism's immunity to infections).

Pollen is widely used because of its therapeutic properties. Pollen extracts demonstrate anti-inflammatory, anti-androgenic, anticancer properties. Moreover, bee pollen has an antibacterial activity, increasing organism's resistance to infection (Abouda, Zerdani, Kalalou, Faid, & Ahami, 2011; Basim, Basim, & Özcan, 2006). Pollen has beneficial effect on lipid metabolism in the liver. It increases organism's resistance to infections and accelerates the treatment of infections. This

bee product helps to increase heart efficiency, and thus helps in the elimination of fluids retained in an organism (Habryka et al., 2016). In addition, it is advisable to feed bee pollen during convalescence after surgical operations, that is, in people performing heavy physical and mental work (Kędzia & Hołderna–Kędzia, 2005).

Pollen can reduce the level of lipids in blood serum correlated with the content of hormones such as insulin, testosterone, and thyroxine (Komosinska–Vassev, Olczyk, Kaźmierczak, Mencner, & Olczyk, 2015). Moreover, small doses of pollen given to the elderly allow the inhibition of atherosclerotic lesions in blood vessels and affect the improvement of cerebral blood flow. The dose of 40 g of pollen administered daily to the patients with heart failure caused a reduction in cholesterol level and a reduction in blood viscosity as well as the concentrations of fibrinogen and fibrin (Campos et al., 2010).

Hypoglycemic effect of pollen is mainly attributed to the presence of unsaturated fatty acids, phospholipids, and phytosterols. Furthermore, the reduced ability of blood platelet aggregation and an increased fibrinolytic system activity were confirmed in humans who consumed the pollen. This indicates an anti-atherosclerotic effect, which protects against heart diseases and stroke (Komosinska–Vassev, Olczyk, Kaźmierczak, Mencner, & Olczyk, 2015). Due to its nourishing and toning properties, pollen can strengthen the blood vessels. The presence of rutin in the pollen increases the flexibility of blood vessels and prevents them from cracking. Pollen has a pronounced effect on the hematopoietic system, so it can be used in case of anemia, especially anemia due to iron deficiency. It can either be used for the treatment of allergic diseases (rhinitis, asthma) or their symptoms could be decreased significantly (Habryka et al., 2016).

Bee pollen supports, among other things, the function of the hematopoietic system. These pollen and bee bread properties are related to the presence of free fatty acids (omega-3, α-ALA) that act as prostaglandin-3 precursors of platelet aggregation. Moreover, increased fibrinolytic activity was confirmed after pollen stimulation. The last important highlight is that the pollen and bee bread are used in treating burn injuries and fighting with post-stroke shock. These can be used in the nutrition of different groups of people, such as adolescents, convalescents, and the elderly, as a rich source of energy and building blocks. In pollen, the content of simple sugars (glucose and fructose) and fats maintains an adequate level of energy in the body, and consuming this after exercise can help relieve fatigue and speed up the recovery of energy expenditure.

Pollen administered with antidepressants can reduce their dose, thereby improving the overall health and well-being. The long-term use of pollen, even in small doses, allows a gradual improvement in mood, restores the will to live, and strengthens the organism (Komosinska–Vassev, Olczyk, Kaźmierczak, Mencner, & Olczyk, 2015). It was observed in the study presented by Al-Salem et al. (2016) that bee pollen can be safely used to relieve oxidative stress, inflammation of nerves.

In recent years, bee pollen is considered to be one of the most bioactive products for human consumption. However, regardless of its characteristics, there are some reports that show a reduced availability of adequate nutrients and bioactive compounds. This is related to the construction of the chemical structure of pollen, and especially the outer lipid layer of the grain. Before consumption, bee pollen should be subject to the process of transformation (Zuluaga et al., 2015). In dried form, it includes a hard shell so that it must be chewed for a long time so that the organism could absorb it properly. Also an alternate method is to grind or powder the bee pollen.

Bee bread strengthens the immune system of an organism and also supports the treatment with pharmaceuticals. It also improves concentration and memory. It can be used during an increased mental effort. In addition, it is also used in apitherapy, that is, treatment using the products of bee origin. Bee bread demonstrates an effect regulating the digestive system functioning. Due to its antimicrobial properties, bee bread is recommended especially during the periods of reduced immunity, for example, in autumn-winter season. Moreover, it reduces allergic reactions. Therefore, bee bread should be used before the period of pollination. It also regulates cholesterol level in the blood and reduces total lipid content, which proves that bee bread has anti-atherosclerotic activity and also is beneficial for heart. In addition, it demonstrates an anti-aging and anti-anemic activity, inter alia, because of the presence of antioxidants in it, and regenerates all cells of the body. Bee bread is widely used in the purification of the liver, acts protectively and detoxicating.

Because bee bread contains vitamin K (Gilliam, 1979a, b), it is very helpful in the treatment and prevention of all types of extravasations, as well as problems arising from the poor condition of the blood vessels (Nagai et al., 2004). The therapy using the products containing vitamin K is often recommended after laser surgery-it effectively and quickly reduces bruises formed on the skin. In China, bee pollen from *Brassica campestris* L. is commonly used as a food additive to enhance organism's immunity against the cancer diseases (Omar, Azhar, Fadzilah, & Kamal, 2016). Wang et al.'s (2013) study demonstrated that the components of pollen, as exemplified by polysaccharides, exhibit significant anti-proliferative activity in colon cancer cell lines.

Bee pollen can be used to supplement chemotherapeutic agents due to its antiproliferative activity and its ability to enhance the chemo-effect even at low concentrations. The molecular mechanism of how bee pollen has an antiproliferative effect will be a very interesting area to explore in future research. In Komosinska-Vassev and et al.'s recent review, the addition of bee pollen can improve early prostate cancer including chemotherapy. In addition, as a supplement, bee pollen may be combined with chemotherapy to treat cancer side effects. Uçar et al.'s (2016) studies showed that bee pollen affects apoptosis and caspase-3 activity in HL-60 cells. This statement indicates that apiculture products can have beneficial effects in the treatment of cancer.

Bee pollen can potentially be used to control some reproductive processes. The data obtained may not only be physiological but also practical. Bee pollen affects secretory activity (release of growth factor IGF-I and steroid hormones progesterone and estradiol) [Kolesarova et al., 2013]. There are also reports of bee pollen's ability to induce apoptosis and stimulation of tumor necrosis factor α (TNF-α) secretion (Anna Rzepecka-Stojko et al., 2012). In addition, due to the activity of substances characterized by bee pollen's antioxidant properties, there may be antineoplastic effects. Such substances affect the inhibition of the formation and removal of reactive oxygen species (ROS) (Denisow, B., & Denisow-Pietrzyk, 2016).

Each bee product is pharmacologically active and may, therefore, be the source of many active substances. Of particular importance are the new products derived from bee products with specified pharmacokinetics and pharmacodynamics, which may be the basis for many new forms of drugs or dietary supplements. In the last few years, natural products like bee bread or pollen can be used as an alternative to antibiotics, as well as to enhance the immune system of humans and animals (Farag & El–Rayes, 2016). It was demonstrated that bee pollen acts as an immunomodulator in that it stimulates a humoral immune response and changes the delayed-type hypersensitivity.

10. Dosage of pollen and bee bread

The use of bee bread is analogous to the pollen. The daily dosage for an adult should be about 20–40 g. It should be noted that there is no possibility of bee bread overdose. It is enough to eat one tablespoon of bee bread every day to regenerate and strengthen an organism. A lower dose of pollen is used in combination with other drugs and in chronic diseases. Bee bread as a product characterized by a stronger activity than the pollen is usually administered in smaller amounts or over a short period of time. In order to increase the digestibility, pollen grains are crushed or dissolved in warm water. In aqueous environment, pollen grains crack after 2–3 h, which leads to the release of nutrients. In addition, pollen may be mixed with many other food products, for

example, with honey, yogurt, and jams. In conclusion, pollen must be thoroughly chewed because its nutrients are used by an organism only on a level of 10%–15% while in raw form. After the mechanical grinding process, the bioavailability of this product's ingredients for organisms increases by 60–80% (Komosinska–Vassev, Olczyk, Kaźmierczak, Mencner, & Olczyk, 2015).

11. Conclusion

After a period of fascination with highly processed products, the return to natural foods, whose nutritional value is confirmed by the results of scientific research, is currently observed around the world. Expectations of the consumers in relation to food are increasing. What consumers demand is that new foods be introduced in the market that are characterized by health-oriented properties, are effective in increasing the overall efficiency of an organism, and are even preventive in the development of certain diseases. Many food producers try to meet the ever-growing consumers' demand for healthy, and above all tasty, products while paying more attention to the quality standards. Consumers have more balanced approach to the diet. They have wide knowledge about the effects of food on health and well-being. They have growing expectations in relation to food. They apply the principle of "you are what you eat"; therefore, the manufacturers try to meet these requirements and look for attractive products adjusted to the current scientific recommendations applicable in human nutrition. Bee bread and pollen contain the nutrients well absorbed by humans. Thus, they allow in supplementing nutritional deficiencies, as well as better adaptation of an organism to adverse environmental conditions, improving the physical and mental state. In conclusion, it can be stated that bee products are characterized by many beneficial biological properties that can be successfully used in food technology and medicine.

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