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Bee Pollen – Nutritional and Toxicological Aspects

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Abstract

Pollen contains nutritional elements – carbohydrates, proteins, lipids, vitamins, minerals, trace elements. The pollen contains also important amount of polyphenolic compounds, primarily antioxidants. Because the pollen is rich in nutrients, honeybee-collected pollen is recommended as a dietary supplement. The product can be used as dietary supplements to enrich food with valuable nutrients performing important functions in the human body. Pollen is a bee product affected by contaminants of various origins. In addition to important nutrients, it may also contain heavy metals that are harmful to human health. May be contaminated from air and soil by heavy metals and pesticides.

1. Introduction

The pollen gathered by honey bees (*Apis mellifera*) is considered like a potential source of energy for human nutrition. Pollen contains nutritional elements like carbohydrates, proteins, amino acids, lipids, vitamins, minerals and trace elements **(Serra Bonvehí and Escolá Jordá, 1997)**. Apart from this the pollen contains also important amount of polyphenolic compounds, primarily antioxidants **(Almeida-Muradian *et al.*, 2005).**
Bee-collected pollen is nutritionally valuable special food, having different health enhancing effects, and is also used in apitherapy **(Bogdanov, 2004)**. This bee product has several pharmaceutical effects, like antibiotic, antineoplastic, antidiarrheic and also as antioxidative agent **(Campos *et al.*, 1997)**.
This review aims to present significant knowledge about pollen and analyze selected nutritional and toxicological aspects of bee pollen.

2. Pollen, types of pollen

It is important to distinguish between three types of pollen:

a) natural, flower pollen, which releases from anthers and it is not process at all.
b) fermented, named also "bee bread", which was hydrolysed by non-reducing sugars and fermented by lactic acid in combs. This pollen is the most valuable in human nutrition.
c) corbicular pollen (bee pollen), which is collected by worker-bees from flowers and then is processed by bee's gland and honey sac secretions.

Pollen grains were characterized the first time in 1682 by Nohamiah Grew. The size of pollen grains is ranged from 2.5 to 250 μm, which have reproduction function and also other physiological functions. Bees form them into loads (size 1.5-2.5 mm) by glands secretions (bee pollen) and carry them on the corbiculas (pollen baskets) to a hive.
In human nutrition are used bee and fermented pollen. Fermented pollen is obtained from honey combs, but this is very laborious. For this reason is mostly used bee pollen. On other hand bee pollen missed some important elements e.g. enzymes, in comparison with fermented pollen, but its nutritional value is still very high. This deficiency can be complete by its consumption in honey **(Žitňanský, 1996)**.
Bee workers form pollen loads on the third pair of legs (corbiculas). They form them from thousand pollen grains which are put together with nectar and glands secretions. The bee pollen in comparison with flower pollen is sweeter and acquire other valuable features **(Chlebo and Čermáková, 2001)**.

Table 1. Elementary chemical composition of bee pollen (%) **(Schmidt and Buchmann, 1992)**

Compound	Average	Range
Proteins	23.7	7.5 - 35
Lipids	4.8	1 - 15
Sugars	27	15 - 45
Ash	3.12	1 - 5

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Table 2. Differences between bee and fermented pollen in % **(Dobrovoda, 1986)**

Type of pollen	Proteins	Lipids	Carbohydrates	Ash	Lactic acid	Active acidity
Bee pollen	24.06	3.33	18.5	2.55	0.56	6.3
Fermented pollen	20.3-21.7	0.67-1.58	24.4-34.8	2.4-2.6	3.06-3.20	4.3

3. Chemical composition and selected nutritional aspects

Chemical composition of bee pollen depends from plant species origin, from composition, moisture and fertility of soil, and also from climatic conditions during production and maturation of pollen grains in anthers. This explains differences in results pollen samples mentioned by different authors **(Dobrovoda, 1986)**. Contrary of other foods, bee pollen is not uniform product. Chemical composition of bee pollen varies widely. It differs on the cause of geographical origin, but also from one locality to other, or during the year. The bee pollen composition documented by tables 1 and 2.

Fresh, bee collected pollen contains about 20-30 g water per 100 g **(Bogdanov, 2004)**. The bee-collected product - pollen can be a good complement to daily diet due to the interesting proportions of proteins, fats and carbohydrates **(Orzáes Villanueva *et al.*, 2002)**.

Pollen (hand-collected or harvested by bees as pollen loads) has been a subject of study for many years because of its importance in bee nutrition and also because it provides a rich source of easily digestible protein and essential amino acids for humans **(Naumkin, 1984, Čeksterite, 1988, 1991; Campos *et al.*, 1996)**.

Protein content in pollen depends on the plant origin. Because of high protein content and rich amino acid composition, pollen has been the subject of numerous studies. The crude protein content has been determined to be close to 25 %. Many papers have reported these values that vary between a large range from 3.8 to 40.8% **(Naumkin, 1991; Serra Bonvehí *et al.*, 1991; Čeksterite, 1991; Serra Bonvehí and Escolá Jordá, 1997; Somerville, 1997)**. Pollen protein content has been the subject of studies conducted in Poland by **Syrocka and Zalewski (1985), Zalewski and Kosson (1985), and Szczęsna (2006a, 2006b, 2006c, 2007a, 2007b)**. Their results were higher than the findings of Spanish scientists (by Polish authors **Szczęsna *et al.*, 1995a** about 30%, according to Spanish studies by **Somerville, 1997** the crude protein level as low as 16 %) **(Serra Bonvehí *et al.*, 1986; Muniategui *et al.*, 1990; Serra Bonvehí *et al.*, 1991; Serra Bonvehí and Escolá Jordá, 1997)**. The crude protein content in the samples of bee-collected pollen by **Szczęsna (2006b)** ranged from 15.80 % DM (dry matter) for the pollen from Poland to 26.13 % DM for the pollen from China. Essential amino acids index EAAI reached value in the range from 97 % for pollen from Korea to 116 % for pollen from China (110 % on average). In all the pollen samples, methionine and cysteine have proven to be the limiting amino acids **(Szczęsna, 2006b)**, which was also found in earlier studies by other authors **(Naumkin 1991; Rogala and Szymaoe 2004)**. High value of essential amino acids index (EAAI=110 %) confirmed high nutritional value of pollen samples collected in Poland, Korea and China (**Szczęsna, 2006a)**. The similar results for CS and EAAI values was received by **Szczęsna (2006b)** for pollen from selected botanical origins. **Szczęsna (2006b)** investigated the protein and amino acid composition of honeybee-collected pollen from selected botanical origins. The crude protein content in the examined samples ranged from 13.06 % DM for *Artemisia* pollen to 24.54 % DM for that of *Sinapis alba*; the mean value was 20.55 % DM. The protein content found in the rapeseed pollen (*Brassica napus* subsp. *napus* L.) was on average 251.13 ± 33.06 $g.kg^{-1}$ **(Fatrcová-Šramková et al., 2008a, 2008b)**.

Carbohydrate fraction constitutes an essential part of honeybee-collected pollen dry matter. The first investigations on the subject were concerned with total sugar content, the distinction being made between reducing and non-reducing sugars **(Szczęsna *et al.*, 1995a)**. The study also showed that the basic sugar composition changes as the product is further processed, during its preservation (drying) and storage **(Szczęsna *et al.*, 1995b)**. **Szczęsna (2007b)** investigated the sugar composition in bee pollen collected in different countries (Poland, South Korea and China). The study showed that sugar content of pollen loads dry matter averages 40 %. As compared to pollen loads samples from South Korea and China those collected in Poland had a significantly higher fructose to glucose ratio. Of all the assayed sugars fructose was found to occur in the highest concentration. It accounted for 46 % of the total sugar content in the tested pollen samples. Glucose was the second highest accounting for 37 %. Monosaccharides expressed as the combined concentration of fructose and glucose accounted for 83 % of the carbohydrate fraction of pollen. When comparing the results from the study by **Szczęsna (2007b)** with those from earlier investigations **(Szczęsna *et al.*, 2002)** it can be seen that the data on the contents of individual sugars in the pollen samples differ considerably. The reason behind those differences is that the study by **Szczęsna (2007b)** was performed on pollen samples that came from different forage plants (different beekeeping seasons, different dates, different countries). The investigations of sugars in pollen loads showed that their minimum content was ca. 30 % DM, monosaccharides expressed as the sum of fructose and glucose accounting for at least 20 % DM.

It was estimated content of sugars in bee-collected pollen samples from *Papaver somniferum* L. Content of sugars was 340.7 $g.kg^{-1}$. Fructose content was 188.5 $g.kg^{-1}$, glucose content 152.2 $g.kg^{-1}$ and glucose/fructose ratio 0.81 **(Fatrcová-Šramková *et al.*, 2008c)**.

The content of the lipid fraction (the so-called "crude fat" or "ether extract") determined by different authors was within a very wide range, depending on the species of plant the pollen originated from, i.e. from 1.5 % **(Standifer, 1966)** to 22.4 % **(Szczęsna *et al.*, 1995b)**. The content of the lipid fraction in the samples of honeybee-collected pollen originating from Poland ranged from 6.74 % DM to 10.99 % DM, i.e. 8.7 % DM on average, and was higher as compared with that reported for Korean (5.5 % DM) and Chinese (6.2 % DM) samples. The mean content of the lipid fraction in the samples from Korea was not statistically different from that of pollen samples from China. The study by **Szczęsna (2006c)** contributes to a precise determination of the composition and content of fatty acids of main pollen species obtained by beekeepers under Polish climatic and soil conditions.

According to different authors ash content of pollen varies from 1.55 % to 6.05 % **(Nation and Robinson, 1971, McLellan, 1977, Youssef *et al.*, 1978, Zalewski and Szymaniuk, 1985, Serra Bonvehí *et al.*, 1986, Szczęsna *et al.*, 1995a, Serra Bonvehí and Escolá Jordá, 1997)**. Polish authors **(Zalewski and Szymaniuk, 1985, Szczęsna *et al.*, 1995a)** found higher values for that constituent with an average of more than 3 % whereas Spanish authors reported values less than 2 % **(Serra Bonvehí and Escolá Jordá, 1997)**. Potassium, magnesium, calcium and sodium were found at the highest concentrations. Iron, manganese, zinc and copper were also relatively high. The investigators emphasize the dependence of the content of individual elements in pollen on its botanical origin.

Szczęsna (2007a) investigated the macro- and micro-elements composition (total ash and selected elements) of the multifloral honeybee-collected pollen harvested in different countries (Poland, South Korea and China). Ash content of the tested samples ranged from 2.08 to 3.19 % of DM for the samples from Poland, from 2.17 to 3.66 % DM for the samples from Korea and from 2.78 to 3.33 % DM for the samples from China. The following elements were assayed in the tested pollen samples: sodium, potassium, calcium, magnesium, manganese, zinc, iron and copper. Regardless of origin, potassium occurred at the highest concentrations in all tested pollen samples (59 % of the total content of minerals). The second largest with respect to content level was magnesium (18 %) followed by sodium (12 %) and calcium (8 %) and the remaining elements accounted jointly about 3 %. The contents of elements in the samples can be put in the following decreasing order: K > Mg > Na > Ca > Fe > Mn > Zn > Cu. It was found that contents of ash and of the minerals varied substantially from sample-to-sample which could be related to different botanical origin.

Melissopalynological analysis of the tested bee pollen samples allowed the placement of the samples within three groups: group I – samples with the predominance of pollen from Brassicaceae family (over 65 %), group II – samples with the predominance of pollen from the genus *Artemisia* (over 64 %), group III – samples of multifloral pollen originated from other ruderal plants (*Rumex*, *Coryphyllaceae*, *Ranunculus*, *Centaurea cyanus*, *Majoran*a type) and from agricultural and horticultural plants (*Rubus* type, *Fragaria*, *Trifolium* type), trees and shrubs (*Syringa*, *Cornus*, *Robinia*, *Salix*) **(Szczęsna, 2006b)**.

The pollen samples containing substantial percentage of pollen of *Artemisia* when compared to samples with a large percentage of *Brassicaceae* pollen and with samples of multifloral pollen were found to contain less ash and to be lower in all tested elements except calcium. The ash content of samples with substantial percentage of *Artemisia* pollen was 2.14 % DM whereas it was 2.71 % and 2.91 % in the two remaining groups, respectively. The ash content of 3% as determined in the study by **Szczęsna (2007a)** for multifloral pollen samples is in agreement with earlier studies both by the author **(Szczęsna *et al.*, 1995a)** and by other Polish investigators **(Zalewski and Szymaniuk, 1985)**. Spanish investigators obtained ash contents of pollen that were much lower being as low as ca. 2 % **(Serra Bonvehí *et al.*, 1986, Serra Bonvehí and Escolá Jordá, 1997)**.

The important part of bee pollen is water soluble vitamins from the group B: vitamin B1, vitamin B2, vitamin B6, pantothenic acid, folic acid, vitamin C. From vitamins soluble in fats are mostly represented by vitamin E and vitamin D **(Neuschlová, 1995)**.

4. Antioxidants, antioxidant and antiradical activity

Antioxidants, inclusive of flavonoids, beta-carotene, vitamin C and E, and selenium are also the part of bee pollen **(Schmidt and Buchmann, 1992)**. Antioxidants are considered as protective substances to free radicals which damage the human organism; and moderate a development of chronic diseases **(Gulcin *et al.*, 2003)**. Studies by **Campos (2000) and Campos *et al.* (2002)** are oriented to antioxidant properties of bee pollen, and they confirmed the high antiradical activity of bee pollen. It seems that antiradical activity is caused by phenolic components. In floral pollen mostly flavonoids, their glycosides and derivatives of cinnamic acid are present **(Markham and Campos, 1996)**. The antioxidant activity of bee pollen has been recognized as a free radical scavenger and as a lipid peroxidation inhibitor **(Campos *et al.*, 1997, Campos *et al.*, 1994)**.

The free radicals damage membranes of different organs cells, including the liver cells, what is considered as primary reason of organism aging. Rats, aged 23 months, were one time a day orally fed by bee pollen (250 mg.kg^{-1}) during one month. This treatment led to improving lipids peroxidation, antioxidant protective system and liver functions, which can relate to natural antioxidants (flavonoids) contained in bee pollen **(Uzbekova *et al.*, 2003)**. **Capcarová et al. (2013, 2019)** also dealt with bee pollen and consumption in rats in research.

Bee-collected pollen is an apicultural product which contains considerable amounts polyphenol substances (8,2 ± 0,3 mg.g^{-1}) which may act as potent antioxidants. Bee-collected pollen extracts show considerable antiradical activity which is significantly increased in the pollen extracts. The highest degree of radical scavenging activity is found in the ethanol extract, which also has highest concentration of polyphenol substances. For this reason, it can be assumed that there is a general correlation between the content of total polyphenols and the antioxidant and radical scavenging activity of the pollen preparations. Thus, the prepared extracts of bee-collected flower pollen may be regarded as effective natural and functional dietary food supplement due to their remarkable content of polyphenol substances and significant radical scavenging capacity with special regard to their nutritional-physiological implications and their health promoting effect **(Kroyer and Hegedus, 2001)**. The antioxidants, antiradical, and antioxidant activity of bee pollen have been studied **(Fatrcová-Šramková *et al.*, 2008a-d, Kačániová *et al.*, 2010)**.

5. Selected toxicological aspects

Pollen is a bee product affected by contaminants of various origins. May be contaminated from air and soil by heavy metals and pesticides. For optimal pollen quality, it is recommended to collect pollen in areas at least 3 km away from the source of contamination, such as intensive traffic, industrial centers and pesticide-treated agricultural areas **(Bogdanov, 2004)**.

While being a natural source of bio-elements pollen can also contain elements harmful to human health: cadmium, lead, mercury and arsenic **(Free *et al.*, 1983, Lipińska and Zalewski, 1989, Migula, 1990, Konopacka *et al.*, 1993, Szczęsna *et al.*, 1993)**. Pollen loads are assayed for heavy metal contents mainly because of the contamination of environment with those metals. The authors of those studies report on ever more frequent cases of admissible contents of those health-compromising metals being exceeded and point to the need for their level in honeybee-collected pollen to be constantly monitored. Pollen production-oriented apiaries should not be located in heavily industrialized areas, in a close proximity of heavy traffic roads or close to large urban agglomerations.

Heavy metals concentrations were analysed in bee gathered (in case of three treatment: dried, frozen, freeze-dried bee pollen) and flower pollen samples. From the heavy metals, in flower and bee pollen, the lead level was 0.64 mg.kg^{-1} and less than 0.1 mg.kg^{-1}, respectively. The contents of mercury were 0.019 mg.kg^{-1} in the flower pollen and ranging from 0.004 to 0.005 mg.kg^{-1} in the frozen, freeze-dried and dried bee pollen. The cadmium concentration in the flower pollen was 0.12 mg.kg^{-1}, and in the bee pollen ranged from 0.22 to 0.26 mg.kg^{-1} **(Kačániová *et al.*, 2008a, b)**.

Various physical, chemical and biological methods can be used to determine environmental contamination, the most popular being the latest **(Madras-Majewska and Jasiński, 2005)**. Several researchers recommend using adult bee bodies and bee products to monitor environmental cleanliness **(Crane, 1984; Jędruszczuk, 1987; Roman, 1997, 1998, 2000; Muszyńska, 1995; Szczęsna *et al.*, 1993; Jabłoński *et al.*, 1995).** The honey bee is one of the major carriers of environmental information. In its way and character of life, it is very closely related to natural conditions and immediately responds to their change. For some properties (easy manipulation, relocation, precise detection circuit, full-area monitoring in the field) it is a suitable object for testing **(Čermáková, 1997)**. In many countries, bees and bee products have been used to assess the degree of environmental pollution **(Loper *et al.*, 1980; Roman, 2000)**. Of bee products, bee pollen and bee bread are very often used as experimental material. Bee bread is a good indicator of contamination because it is exposed to direct contamination of the environment **(Madras-Majewska and Jasiński, 2005)**.

Bees, but especially the pollen and propolis, are a very good and sensitive bioindicator of the state of the environment. They can be used to monitor environmental pollution, especially toxic elements. They are used to monitor the occurrence of some chemical elements that pose a potential risk to humans. Such risk elements include aluminum, arsenic, antimony, beryllium, chromium, cadmium, nickel, lead, mercury, selenium. These elements may, at a certain concentration, endanger human health, and children are very sensitive. These elements inhibit the enzymatic activity in the body, do not disintegrate, do not undergo metabolic breakdown and accumulate in the body. They penetrate the body by inhalation, penetration (through the skin) and through the food chain **(Čermáková, 1997)**.

The contamination of bee products (nectar, pollen, honeydew, etc.) occurs through air, water, plants, soil, and also by transport to the beehive by bees. Bees and their products can contaminate air and soil containing heavy metals, mostly from industry and transport **(Bogdanov, 2005)**.

Monitoring and analysis of heavy metals in pollen have a long history. **Bogdanov (2005)** summarized a number of findings from published studies on pollen, beeswax and propolis contamination with heavy metals **(Altmann, 1983; Cesco *et al.*, 1994; MAFF, 1995; Leita *et al.*, 1996; Conti and Botre, 2001; Madras-Majewska and Jasiński, 2003)**. Values vary and range widely:

Lead: in honey 0,01 - 1,80 mg.kg^{-1}, in pollen 0,02 - 3,90 mg.kg^{-1}, in beeswax 0,06 - 6,20 mg.kg^{-1}, in propolis 0.003 - 461.0 mg.kg^{-1}.

Cadmium: in beeswax 0,01 - 0,10 mg.kg^{-1}, in honey 0,03 - 2,10 mg.kg^{-1}, in pollen 0.05 - 2.30 mg.kg^{-1}, in propolis 0.006 - 3.8 mg.kg^{-1}.

Bees can also serve with their products as bio-indicators of heavy metal contamination, especially lead **(Altmann, 1983; Cesco *et al.*, 1994)**. Lead and cadmium are considered to be the major toxic heavy metals and are thus the most studied subject **(Bogdanov, 2005)**.

The heavy metal content in the pollen was analyzed to assess the state of environmental contamination by these metals. **Kačániová *et al.* (2008a, 2010)** analyzed the presence of heavy metals (cadmium, mercury, lead) in bee pollen samples (after three treatments - after drying, freezing and lyophilizing pollen) and in flower pollen samples. The results of the experiments are presented in Table 3.

Table 3. Heavy metal content in flower and bee pollen (mg.kg^{-1}) **(Kačániová *et al.*, 2008a, 2010)**

Heavy metals	Flower pollen *	Bee pollen *	
Cadmium	0.120	dried	0.25
		frozen	0.22
		lyophilized	0.26
Mercury	0.019	dried	0.005
		frozen	0.004
		lyophilized	0.004
Lead	0.640	dried	< 0.1
		frozen	< 0.1
		lyophilized	< 0.1

* year 2007

Cadmium does not disintegrate in the soil, it remains in the soil, resulting in contamination of the plant mainly by simple diffusion through the root system. Cadmium is very mobile in plants. It binds to part of the protein molecule. Although pollen grains are male sex cells and are protected in flower buds, they may be contaminated. Research has shown that pollen is very suitable for the indication of cadmium because it contains many protein substances with cadmium-bound groups (with sulfhydryl groups SH-). There is currently a trend of increasing cadmium content in the environment. The sources of cadmium that have a negative impact on the human organism are, for example, waste water, industrial fumes, transport **(Šalgovičová and Zmetáková, 2006)**.

Kačániová *et al.* (2008a, 2010) report cadmium concentrations in flower pollen of 0.12 mg.kg^{-1} and bee pollen of 0.22 - 0.26 mg.kg^{-1} (Table 3). The cadmium content was lower in the flower pollen than in the bee pollen, but other heavy metals (lead and mercury) reached a higher content in the flower pollen. **Čermáková (1997)** found that in selected monitored areas (Bardejov, Spišská Nová Ves, Gelnica, Ružomberok and Bratislava) the maximum cadmium value in the pollen was measured in 1989 at 0.172 mg.kg^{-1}, while in 1995 the maximum value was 0.720 mg.kg $^{-1}$. Higher values were found in samples from agricultural production areas. **Patruica *et al.* (2008)** report the cadmium content of the fermented (mixed and sunflower) pollen presented in Table 4.

Mercury enters the atmosphere by evaporation from decaying minerals containing mercury, from volcanic gases and evaporation from the oceans. The most dangerous forms for the organism are mercury vapors and alkyl mercury compounds (methyl mercury) **(Čermáková, 1997)**. Exposure to mercury, which may be represented by an inorganic form and an organic form that is more toxic, may cause central nervous system disorders **(Šalgovičová and Zmetáková, 2006)**. High concentrations of mercury are harmful to humans or bees. Mercury contamination was found in pollen, nectar, honeydew, bee-collected products. The significant development of heavy industry and automobile transport has caused a high content of mercury in the environment **(Madras-Majewska and Jasiński, 2005)**. According to **Kačániová *et al.* (2008a, 2010)** the mercury content in the flower pollen was 0.019 mg.kg^{-1}. The range of 0.004 - 0.005 mg.kg^{-1} in bee pollen (Table 3) does not indicate differences between dried, frozen and lyophilized pollen. **Madras-Majewska and Jasiński (2005)** evaluated the mercury content of bee bread (in fermented pollen) from different regions of Poland. They state that if mercury contamination in selected areas is high, bee-bread contamination with this element is also high. Overall, it was observed that the mercury content in bee pollen was low and did not exceed the standards, while the reported limit for children and infants was according to the Ministry of Health in Poland **(Rozporządzenie Minister Zdrowia, 2003)** 0.01 mg.kg^{-1}. All samples of bee bread examined contained mercury. The content was 18.10^{-5} - 795.10^{-5} mg.kg^{-1}, the average content was 92.10^{-5} mg.kg^{-1}. A similar average mercury content in bee bread was observed by Żarski et al. (1996), namely 91.10^{-5} mg.kg^{-1}.

The concentration of lead in the environment is influenced by the amount of emissions from leaded gasoline engines, which represent 85 % of the total lead volume in the atmosphere. The decrease in lead content in the environment is not yet significant, although the positive impact of ecological petrol production is visible **(Čermáková, 1997)**. Adverse effects of lead on humans have been proven **(Šalgovičová and Zmetáková, 2006)**. According to **Kačániová *et al.* (2008a, 2010)** a lead content of 0.64 mg.kg^{-1} and bee pollen of less than 0.1 mg.kg^{-1} was found in the flower pollen (Table 3). **Patruica *et al.* (2008)** report the lead content of the fermented (mixed and sunflower) pollen, presented in Table 4.

Table 4. Heavy metal content (ppm) in different types of pollen **(Patruica *et al.*, 2008)**

Element	Mixed flower pollen	Rapeseed pollen	Sunflower pollen	Mixed fermented pollen	Sunflower fermented pollen
Cadmium	0.011	0.015	0.006	0.006	0.002
Lead	0.010	0.008	0.006	0.003	0.003

Arsenic is found primarily in the form of silver, lead and copper sulfides. In the metallurgical industry, especially in the melting of copper, the concentrations of arsenic in the atmosphere and in the soil are significantly higher. It is similar in the combustion of younger coal. Toxicity of arsenic depends on its chemical form, mainly on arsenic ions (As^{3+}), which are more toxic than methylated. Prolonged exposure to arsenic can cause various diseases, for example, it can cause damage to the central nervous system. The arsenic content fluctuates during the season, it is higher in the spring months, then there is a decrease. This is probably due to the immission gradient after the winter heating season and the long-term transmission of immissions **(Čermáková, 1997)**.

Other authors also note that pollen is not only a natural source of minerals, but may also contain elements harmful to human health: cadmium, lead, mercury and arsenic **(Free *et al.*, 1983; Lipińska and Zalewski, 1989; Migula, 1990; Konopacka *et al.*, 1993; Szczęsna *et al.*, 1993)**. The authors draw attention to the frequent causes of exceeding the acceptable contents of these health-damaging elements and to the need for constant monitoring of their levels in the bee pollen. Pollen production hives should not be located in industrial areas, in close proximity to busy roads or large urban agglomerations **(Szczęsna, 2007a)**. The long half-life of metals, their accumulation in the body can cause long-term stress on the body and toxic effects. The toxicity of various metals can be varied by the interaction of metals and other substances. Selenium can reduce the toxicity of methylortute and zinc in turn the toxic effect of cadmium. At present, levels of toxic metal concentrations in the environment are relatively low, with the exception of areas with intensive industrial activity, so that direct damage to health may not occur during human life.

Systematic monitoring of the concentration of toxic metals in the atmosphere, soil, water and sanitary and technological-preventive measures is the primary method for reducing metals in the environment and thus in the food chain. The timely capture of increased amounts of contaminants in the environment is very important. Therefore, it is important to use pollen collected by bees as one of the sensitive bioindicators of environmental pollution **(Čermáková, 1997)**.

Table 5. Heavy metal content in pollen samples ($mg.kg^{-1}$) **(Chlebo and Čermáková, 2001)**

Heavy metals	Cadmium	Mercury	Lead	Arsenic	Chromium
1st analysis	0.180	0.018	1.700	0.605	0.650
2nd analysis	0.043	0.003	0.380	0.182	0.120
Limit	0.100	0.050	1.000	1.000	0.500

1st analysis: year 1990, 2nd analysis: year 1999

According to **Chlebo and Čermáková (2001)**, pollen contamination is threatened mainly by industrial pollutants and the application of plant protection products. In 1990 and 1999 the authors investigated the presence of selected chemical elements (Table 5) in sixteen pollen samples from four regions of Slovakia with high ecological load (Stredny Spis, Ruzomberok, Horna Nitra and Bratislava). In the given situation, the air quality in Slovakia was generally satisfactory. This was not only a reduction in production but also a greening of production for large exhaled producers. The risk of contamination by pesticide residues comes to the forefront when pollen sources are important crop plants such as rapeseed, sunflower and others.

6. Conclusion

In the world marked the bee pollen is mostly used as food supplement in the form of capsules, granules, tinctures, tonics, cereal bars, sweets etc. Partly it is used for animal feeding, above all bumblebees, honey bees and race-horses. Pollen has been shown to be an excellent dietary component in diets for specialty or valuable animals. Nowadays the possibilities of bee pollen utilization are underrated whereby manufacture potential exists. It would also be advisable to continue and extend investigations into the composition and contents of honeybee-collected pollen. Following studies are needed to enable the species-oriented production of bee pollen characterized by a high content of valuable nutrients.

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Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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