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CALCIUM IN EDIBLE INSECTS AND ITS USE IN HUMAN NUTRITION

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ABSTRACT

Calcium is one of the most problematic substances in human nutrition. Nutrition in the present population is not optimal, because of insufficient consumption of milk and dairy products. Due to the expanding interest of specialists and the general public about entomophagy, as well as increase of the EU interest in this type of food, there is a need to consider the use of edible insects as an alternative source of nutrition. From the perspective of edible insects as a source of calcium, edible insects could be considered as a possible source of calcium for enriching the diet and also as a substitute for people with lactose intolerance and allergies to other categories of foods rich in calcium. Of the six analysed species of edible insect, *Bombyx mori* had the highest calcium content, almost comparable to semi-skimmed cow's milk. *Gryllus assimillis* can also be a rich source of calcium as well as other analysed species. The lowest content of calcium was detected in *Zophobas morio*. Common meat (chicken, beef, pork) has lower calcium content comparing with all analysed species of edible insect (*Apis mellifera, Bombyx mori, Gryllus assimillis, Locusta migratoria, Tenebrio molitor, Zophobas morio*). Therefore, the selected species of edible insect could serve as an alternative source of calcium for people with lactose intolerance and allergies to soy. Phosphorus level in human body is closely related to calcium in the calcium-phosphate metabolism, therefore phosphorus level was detected in these samples too. *Bombyx mori* had the highest phosphorus content and the lowest content of phosphorus was measured in *Zophobas morio* samples.

Keywords: calcium; phosphorus; edible insects; nutrition; health

INTRODUCTION

Edible insects are part of the traditional cuisine of many nations. It is possible to consume more than 2,000 species of edible insects **(Bednářová et al., 2013)**. Although nowadays insects are not a traditional food in Western culture, increasing public interest gradually raises its importance as a source of nutrition **(DeFoliart, 1992)**. Edible insects reproduce rapidly, they are easy to breed, and have a low environmental footprint. Therefore they could become an important and valuable source of nutrition not only in the developing countries **(Kinyuru et al., 2013)**, but also a rich source of various nutrients, such as iron, zinc, or calcium as a part of a special diet.

Calcium is one of the most problematic substances in human nutrition. Considering the fact that the milk and dairy products are often the main sources of calcium, their insufficient consumption is quite unfavourable from a nutritional point of view **(Pánek et al., 2002; Habánová, 2005)**. Calcium is the main mineral constituent of the human body. It is in bones and teeth (99%) as calcium phosphate. The total content of calcium in the body is about 1500 grams **(Velíšek, 2002)**. Calcium effects metabolism of phosphorus, magnesium, manganese, zinc and copper. It plays an important role in maintaining homeostasis. Furthermore, it is necessary for blood clotting **(Horniaková et al., 2010)**. Calcium absorption occurs in the small intestine and depends on the chemical form of calcium and composition of the diet. Phytic acid and fibre reduces resorption, while its resorption increases with higher dietary protein intake **(Velíšek, 2002)**.

Body's ability to regulate the calcium level is relatively low. Therefore the organism is unable to compensate its level in low-income or reduced resorption, which depends mainly on vitamin D and parathyroid hormone, age, gender, pH of small intestine, and furthermore on the intake of an antacid and phosphorus. Also the reabsorption in the kidneys, the penetration of calcium from plasma into the bone tissue and from bone tissue into the blood, secretion and absorption in the intestine and renal excretion is important **(Pánek et al., 2002)**.

When inability to absorb calcium from the intestine occurs from various reasons, it leads to softening and deformation of the bones. In children this disease, which occurs mainly in the first two years of life, is called rachitis. In adults the main illness caused by the absence of calcium is osteoporosis, characterized by bone thinning and skeletal pain. Bones lose strength and risk of fractures increases **(Pánek et al., 2002)**.

Lack of calcium in the diet may manifest especially in women during the postmenopausal period with osteoporosis and senile osteoporosis. This problem affects not only women but also men. As stated by **Abraham (1991)**, manifestation of osteoporosis depends on many factors that can be affected. One of them is good and balanced nutrition. Especially in childhood and adolescence it is necessary to ensure an adequate intake of calcium to cover the loss of calcium in urine and faeces. Calcium deficiency leads to an increased risk of osteoporosis and bone fractures.

Calcium intake in the diet therefore becomes one of the major factors that have a direct impact on the quality of bone tissue and its structure. Excessive calcium mobilization from bones or poor kidney function lead to increasing saturation Ca-oxalate and Ca-phosphate in the urine and leads to hypercalciuria. Hypercalciuria is the main cause of calcium oxalate urolithiasis, which affects up to 80% of patients with urinary stones **(Prié, et al., 2001)**.

Calcium intake has decreased during recent years. It is lower by 12 - 15%, but its deficit during the childhood and adolescence may be up to 40%. According to health recommendations the optimal daily dose is 800 mg of calcium per day for adults. Special recommendations apply for women during pregnancy and lactation, 1200 mg per day. Increased calcium intake is important also for older children and adolescents (800 - 1200 mg/day). The recommended daily dose for children under one year is 400 - 500 mg/day **(Velíšek, 2002)**.

Major source of calcium in the common diet are milk and dairy products **(Table 1)**. Lactose intolerance and allergy to milk and dairy products are one of the most common problems of reduced calcium intake in the diet. One of possible alternatives to substitute calcium in milk and dairy products is poppy or fishes, and soybean among legumes **(Velíšek, 2002)**. However, these foodstuffs can also be allergenic or limiting for some dietary reasons **(Bednářová et al., 2013)**.

Edible insects could be used to eliminate the lack of calcium for people with special dietary requirements as well as a non-traditional source of calcium. The calcium content of edible insects is largely influenced by the feed. Diets high in calcium can increase the calcium content in insect 5 - 20 times **(Finke, 2002)**. The benefit of calcium intake in the form of edible insects is its better utilization comparing to plants **(Theobald, 2005)**, where the calcium is bound as calcium oxalate, phosphate and phytate **(Pánek et al., 2002)**.

The consumption of insects does not have only the positive aspects, but brings also various risk factors. Besides nutritionally beneficial ingredients, insects may also contain toxic or antinutritional substances. As with other foods of this kind (e.g. shellfish) allergic reactions may appear. Allergies can be caused by allergens injectant (bees, wasps, and ants) **(Koterba and Greenberger, 2012)**, contactant allergens or inhalant allergens (e.g. cast skins, excreta). Therefore, caution is recommended in case of handling material from edible insects and in case of the first consumption of edible insects **(Rumpold and Schlüter, 2013)**. Cases of botulism, food poisoning and parasites **(Belluco, et al., 2013)** may occur. E.g. steroids, pederin or cyanogenic and cardiac glucosides, as a chemical defence mechanism against insectivores, may be naturally contained in the insect.

Therefore, some of the insects are not edible, just like other kinds in vegetable or animal area **(Rumpold and Schlüter, 2013)**. Consumption of these insects can lead to visual disturbance, nausea, vomiting, edema, jaundice, hepatic carcinoma etc. **(Berenbaum, 1993, Belluco, et al., 2013)**. Furthermore, wild insects may contain pesticides. Therefore, eating normally safe insect species that were harvested in the open air, it may not be safe. However, the controlled breeding of edible insects in a non-toxic environment eliminates these risks **(Rumpold and Schlüter, 2013)**.

Phosphorus level in human body is closely related to calcium in the calcium-phosphate metabolism. The ratio of phosphorus and calcium in human nutrition should be around 1:1.5. The daily requirement of phosphorus is about 1.0 to 1.2 g. The Recommended Dietary Allowance

Table 1 The calcium content in various type of food **(Velíšek 2002)**.

Type of food	min. [mg.kg^{-1}]	max. [mg.kg^{-1}]
Cheese	1500	12000
Fishes	60	5200
Soy	1300	1800
Egg yolk	1300	1400
Semi-skimmed cow's milk	1100	1300
Pea	1100	1300
Beans	300	1800
Spinach	700	1250
Lens	400	750
Breast milk	250	310
Cauliflower	180	310
Strawberries	180	260
Tomatoes	60	140
Chicken	60	130
Beef	30	150
Pork	50	90

Table 2 Dry matter (DM) and ash of samples used for calcium and phosphorus content analysis **(Bednářová et al., 2013)**.

Type of edible insect	Dry matter [%]	Ash [g/100 g DM]
Bombyx mori	28.22	6.55
Apis mellifera	17.33	5.16
Locusta migratoria	31.56	8.32
Gryllus assimillis	33.28	4.26
Tenebrio molitor	37.45	3.84
Zophobas morio	40.61	3.61

(RDA) for adults is about 700 mg/day **(Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, 1997)**. Phosphorus is an important component of bones and teeth, which give them their strength and is important for metabolism. Phosphorus with nucleotides ensures the transformation of energy (ATP) and with sugar participates in glycolysis. Phosphorus in the human body and in the diet is found in the phosphates form. A good source of phosphorus is milk, dairy products, meat, fish, eggs and pulses. Phosphorus bound in phytate (for example in cereals) is very little available, therefore plant foods are the worse source of phosphorus **(Horniaková et al., 2010)**.

A phosphor deficiency can be in case of pregnant and lactating women (RDA up to 1800 mg/day), adolescents (RDA to 1250 mg/day) **(Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, 1997)**, people with digestive disorders, people with anorexia nervosa, alcoholics, etc. The lack of phosphorus causes deterioration of reproduction, later sexual maturation in children and malfunction ovarian cycle in women. Women with phosphorus deficiency give birth to babies susceptible to disease **(Horniaková et al., 2010)**. In the case of excess of phosphorus (high consumption of cola beverages, meat products and processed cheese), calcium intake is impaired **(Pánek et al., 2002)**.

The topic of this article describes the analysis of the calcium and phosphorus content in selected species of edible insects (*Apis mellifera* - AM, *Bombyx mori* - BM, *Gryllus assimillis* - GA, *Locusta migratoria* - LM, *Tenebrio molitor* - TM, *Zophobas morio* - ZM) and its comparison with conventional foods and assessment of its presumed potential for human nutrition. The selected species are accepted by the public in the Central Europe as species usable in the food industry **(Bednářová et al., 2013)**.

MATERIAL AND METHODOLOGY

All insect species used in this experiment were purchased from institutions and companies in the Czech Republic. All these institutions and companies have a long experience in breeding insects. Bee brood was purchased from the company Přidal Brno. BM caterpillars were purchased from farms at the Masaryk University in Brno. Other species were purchased from company Frýželka Brno.

Preparation of insect samples for analysis

GA and LM nymphs and TM and ZM larvae were purchased alive, left starving for two days without food, and consequently stored in the freezer. AM larvae and pupae were removed from honeycombs with tweezers before the analysis. Bee brood was purchased frozen.

BM caterpillars were purchased alive. They were stored under laboratory conditions (temperature 22 °C, humidity 42%) in sealed plastic containers without food.

Individuals who created the pupa were removed from the containers and immediately frozen. For entomophagy these individuals are optimal, because they have the largest size. Pupae were stored in a freezer and later used for nutritional analysis. All samples for calcium and phosphorus content analysis were randomly chosen from storage boxes from the freezer. Basic nutritional properties of the samples (dry matter, ash) are shown in Table 2 **(Bednářová et al., 2013)**.

Calcium and phosphorus content analysis

The concentrations of calcium and phosphorus nutritional parameters were determined after dry-ashing of the sample at 550 °C in a furnace. About 0.5 g of the sample was taken for the analysis. The ash was dissolved in 10% HCl, filtered and made up to standard volume with deionised water **(Omotoso, 2006)**. The analysis was carried out using the atomic absorption spectrophotometer (AAS, model Varian Spectra AA 300) **(Adeduntan, 2005)**.

RESULTS AND DISCUSSION

The largest amount of calcium had BM (min. / max. 1006 / 1149 $mg.kg^{-1}$), which is comparable to semi-skimmed cow's milk and to pea among the vegetable commodities. The disadvantage of this species is its low dry matter content **(Bednářová et al., 2013)**. Comparison of the calcium content in tested species of insects and some species of edible insects, which has been found by other authors, is shown in Figure 1.

GA had the second largest calcium content (min. / max. 677 / 782 $mg.kg^{-1}$) comparable to spinach and lentils. Among the observed species, GA has the lowest content of fiber **(Bednářová et al., 2013)**, so it is possible to assume a better utilization of calcium **(Hronek, 2004)**. The lowest calcium content was detected in ZM (min. / max. 151 / 179 $mg.kg^{-1}$). All analysed species had higher calcium content comparing to commonly eaten meat. For example very popular chicken meat has an average calcium content 95 $mg.kg^{-1}$. AM (min. / max. 460 / 540 $mg.kg^{-1}$), TM (min. / max. 196 / 501 $mg.kg^{-1}$)

and LM (min. / max. 265 / 305 mg.kg^{-1}) have an average calcium levels comparable with strawberries and cauliflower **(Velíšek, 2002)**. Their value is approximately twice comparing to that of meat.

Analysis of the calcium content in other surveyed edible insect species reported similar concentration of calcium. For example **Hyun et al. (2012)** reported for grasshopper 844 mg.kg^{-1}, **Banjo et al. (2006)** found in *Analeptes*

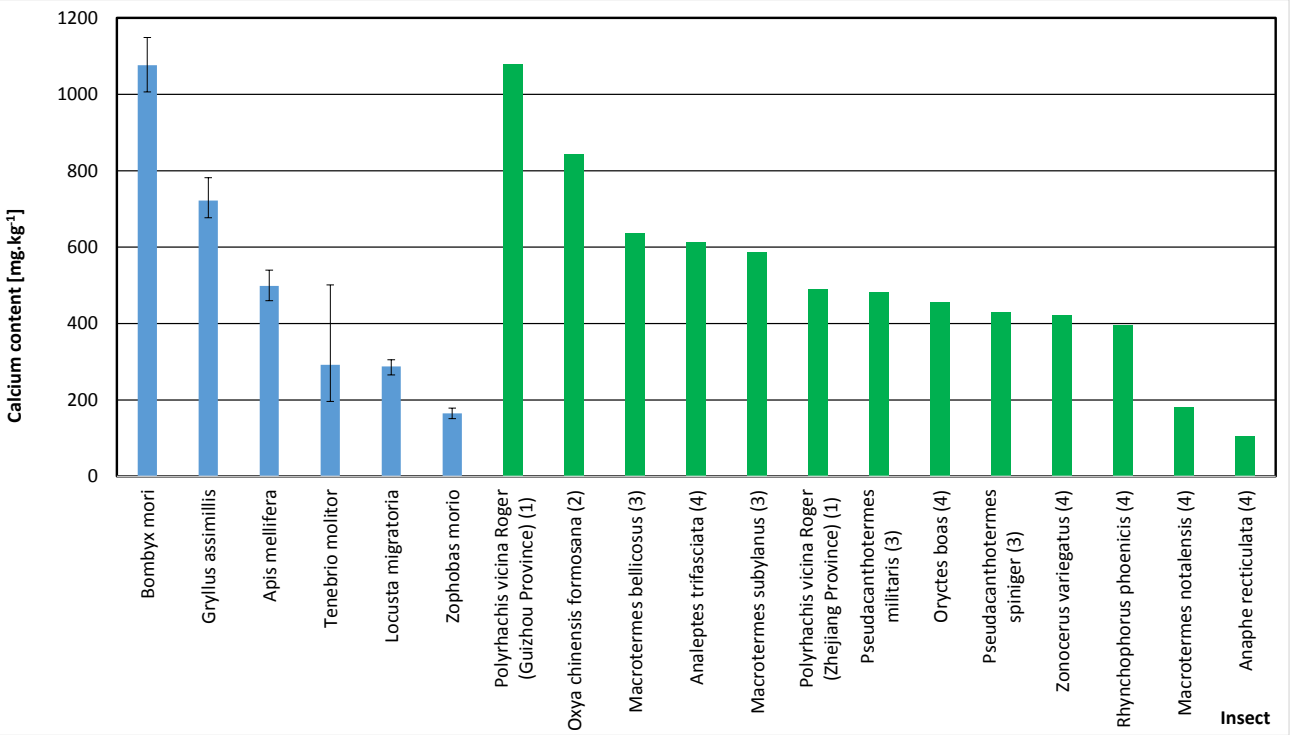

Figure 1 Comparison of the calcium content in tested species of insects (blue) and some species of edible insects, which has been found by other authors (green). Authors: (1) Bhulaidok et al., 2010; (2) Hyun et al., 2012; (3) Kinyuru et al., 2013; (4) Banjo et al., 2006.

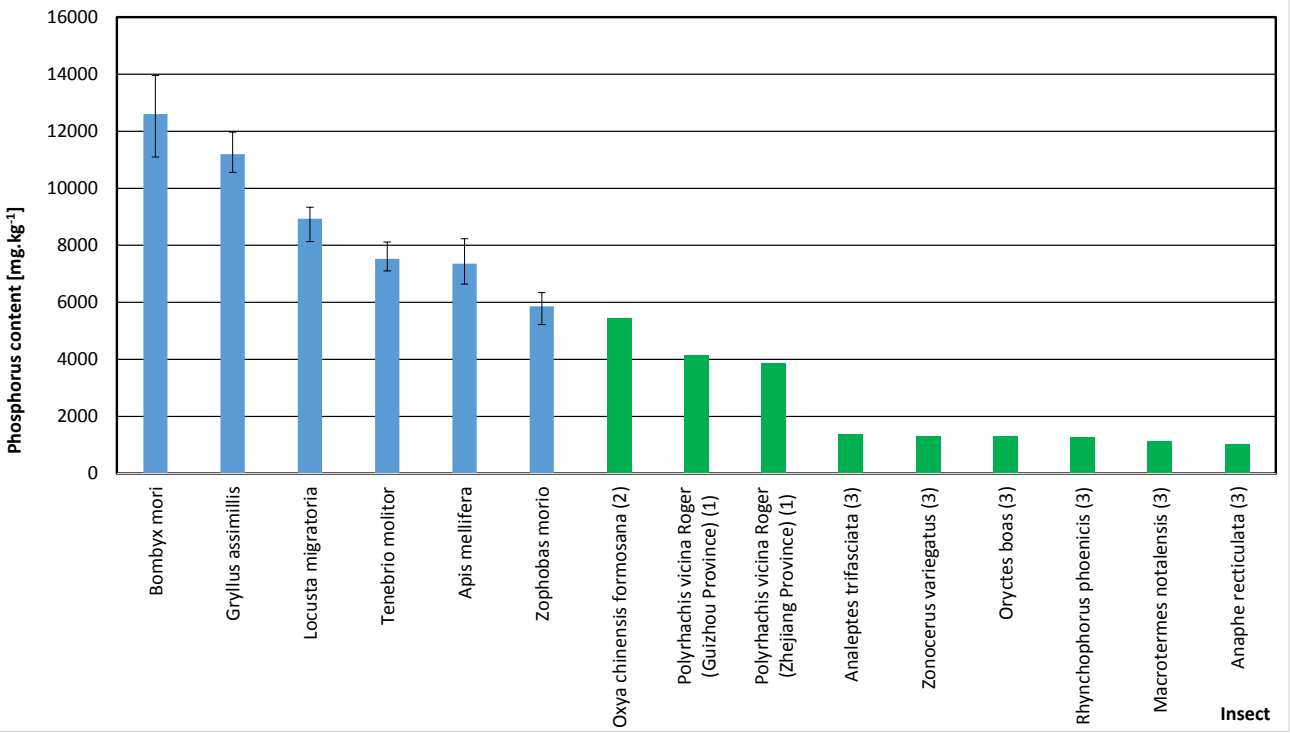

Figure 2 Comparison of the phosphorus content in tested species of insects (blue) and some species of edible insects, which has been found by other authors (green). Authors: (1) Bhulaidok et al., 2010; (2) Hyun et al., 2012; (3) Banjo et al., 2006.

trifasciata 613 mg.kg^{-1} and **Bhulaidok et al. (2010)** for edible black ants 1080 mg.kg^{-1}.

These results indicate that the selected species of edible insects could serve as an alternative source of calcium for people with lactose intolerance and for people with soy allergies.

Analysed insect species (BM, GA) rich in calcium are not suitable for patients with hypercalcemia. In this case the diet with a reduced content of calcium is recommended **(Kato et al., 2004)**. For these patients, it is possible to use bee brood as an alternative source of nutrition **(Finke, 2005)**.

Comparison of the phosphorus content in tested species of insects and some species of edible insects, which has been found by other authors, is shown in Figure 2. BM (min. / max. 11100 / 13960 mg.kg^{-1}) had again the largest amount of phosphorus among the samples. The second largest amount of phosphorus was detected in GA (min. / max. 10560 / 11970 mg.kg^{-1}). LM, TM and AM have a lower amount of phosphorus, which are comparable with cheese, soy beans and black tea **(Velíšek, 2002)**. The lowest phosphorus content was measured in samples of ZM (min. / max. 5220 / 6340 mg.kg^{-1}). Analysis of the phosphorus content in other surveyed edible insect species reported lower concentration of phosphorus. It is possible that this difference is caused by different environment of breeding and feed with varying amounts of phosphorus.

CONCLUSION

Due to the expanding interest of specialists and the general public about entomophagy, as well as increase of the EU interest in this type of food, there is a need to consider the use of edible insects as an alternative source of nutrition. From the perspective of edible insects as a source of calcium, edible insects could be considered as a possible source of calcium for enriching the diet and also as a substitute for people with lactose intolerance and allergies to other categories of foods rich in calcium. Of the six analysed species of edible insect, BM had the highest calcium content, almost comparable to semi-skimmed cow's milk. A rich source of calcium can also be GA, as well as other analysed species.

Phosphorus level in human body is closely related to calcium in the calcium-phosphate metabolism, therefore phosphorus level was detected in these samples too. BM and GA had again the largest content of phosphorus among the samples and the lowest content of phosphorus was measured in ZM samples.

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