



Tomas Bata University in Zlín
Library

Mineral profile of cricket powders, some edible insect species and their implication for gastronomy

Citation

KOSEČKOVÁ, Pavlína, Ondřej ZVĚŘINA, Marie PĚCHOVÁ, Martina KRULÍKOVÁ, Eva DUBORSKÁ, and Marie BORKOVCOVÁ. Mineral profile of cricket powders, some edible insect species and their implication for gastronomy. *Journal of Food Composition and Analysis* [online]. vol. 107, Academic Press, 2022, [cit. 2023-11-09]. ISSN 0889-1575. Available at <https://www.sciencedirect.com/science/article/pii/S0889157521005408>

DOI

<https://doi.org/10.1016/j.jfca.2021.104340>

Permanent link

<https://publikace.k.utb.cz/handle/10563/1010764>

This document is the Accepted Manuscript version of the article that can be shared via institutional repository.



TBU Publications

Repository of TBU Publications

publikace.k.utb.cz

Mineral profile of cricket powders, some edible insect species and their implication for gastronomy

Pavλίna Kosečková^a, Ondřej Zvěřina^{a,*}, Marie Pechová^a, Martina Krulíková^a, Eva Duborská^b, Marie Borkovcová^c

^a*Department of Public Health, Faculty of Medicine, Masaryk University, Brno, Czech Republic*

^b*Institute of Laboratory Research on Geomaterials, Faculty of Natural Sciences, Comenius University in Bratislava, Slovakia*

^c*Department of Food Analysis and Chemistry, Faculty of Technology, Tomas Bata University in Zlín, Czech Republic*

*Corresponding author: E-mail address: zverina@med.muni.cz (O. Zvěřina).

Abstract

Entomophagy is proclaimed as a sustainable nutritional strategy due to the high protein content in edible insects. As it turns out, it may also represent an effective tool for increasing dietary intake of nutrients that are frequently deficient. Cricket powder (CP) appears to be the simplest way. The objectives of this work were to determine the contents of fourteen minerals in CPs and in insect species namely, house cricket, yellow mealworm, desert locust, and superworm. To assess these insect species as sources of minerals with respect to the dietary recommended values (DRV) for some minerals, and to determine mineral enrichment level of some recipes with using CP. Samples were analyzed by means of high-resolution continuum source graphite furnace atomic absorption spectrometry and flame atomic absorption/emission spectrometry. These insect species can be considered as a uniform source of Fe. The species of house cricket, yellow mealworm, and desert locust would provide more than the DRV for Zn, Cu, and P. Replacing 10 % of the wheat flour with CP in bread and pasta recipes increases Zn content by 92-107 %. Finally, the low Cd and Pb contents indicate that the consumption of the given insect species presents no risk.

Keywords: Entomophagy, house cricket powder, edible insect, trace elements, potentially toxic elements

1. Introduction

Despite the fact that using insects as a food has been a feature of human activity since prehistoric times and insects have formed a major part of the human diet for thousands of years, entomophagy is only now becoming an evolving trend in western nutrition and in the food industry (**Van Huis et al., 2013**). In contrast to some African, Asian and Latin American countries, where the tradition of consuming edible insects has persisted, in Europe and the US, the consumption of insects has been strongly suppressed by cultural preconceptions and eating habits. Nowadays, interest in entomophagy has returned and is growing worldwide. In Europe, the "Novel Food" Regulation of 2018 may have contributed to this trend (**Regulation EU, 2018**). Since edible insect products, such as cricket flour,

began to appear on the market, edible insects have gradually moved from gastronomic experience to a daily diet.

Demand for edible insects in European countries is increasing for several reasons, the main one being a reduction in consumption of meat (e.g. flexitarianism). Edible insects may offer a similar nutritional profile to meat and a lower risk of the transmission of zoonoses such as H1N1 influenza and BSE (**Persistence Market Research, 2018**). In addition, their breeding seems to offer advantages over the breeding of livestock such as higher feed conversion efficiency, higher production per unit area, and the reduced consumption of water and energy. Furthermore, the breeding of insects for food usually raises fewer ethical concerns (**Pimentel et al., 1975; Pimentel, 2004; Paoletti and Dreon, 2005; Steinfeld et al., 2006**).

Edible insects are usually appreciated for their relatively high energy content and the quality of their protein with an amino acid profile corresponding well to human nutrition. Edible insects contain between 10 and 35 g of protein per 100 g of fresh weight depending on species and developmental stage, etc. (**Bukkens, 1997**). At the most positive end of the range, insects may provide even more protein than meat, chicken eggs, or dairy products (**MIček et al., 2014**). They also contain an optimal fatty acid profile, rich in monounsaturated and/or polyunsaturated fatty acids (**Nowak et al., 2016**). Furthermore, the basic component of insect shells is chitin, a great source of insoluble dietary fiber (**Whistler, 1993**).

As for micronutrients, **Rumpold and Schluter (2013)**, compiling 236 nutrient compositions of edible insects, determined 100 g of insect material to be a generally rich source of vitamin B2, B5 and B7. Crickets, grasshoppers, locusts, and beetles were also rich in folic acid.

Edible insects are also interesting for their high contents of particular minerals, including iron (Fe), zinc (Zn), calcium (Ca), potassium (K), sodium (Na), phosphorus (P), manganese (Mn), magnesium (Mg) and copper (Cu), with the potential to achieve the dietary reference value (DRV) for some of them in a 100 g portion (**Finke, 2002; Rumpold and Schluter, 2013; MIček et al., 2014; Kouřimská and Adámková, 2016**). The mineral composition is influenced by many factors such as harvesting season, geographical location, living conditions (whether insects are harvested in the wild or bred on a farm), and feed (**Payne et al., 2016a, b**).

The bioaccessibility rate of minerals in insects is also the subject of current investigation. During processing (e.g. boiling), interactions between minerals and other substances (such as chitin, proteins and phytochemicals) can occur, which can decrease the bioaccessibility of some minerals (**Manditsera et al., 2019**). In insects, Fe is found predominantly in non-heme form (ferritin, holoferritin and cytochromes); only some species contain hemoglobin, and no species contain myoglobin (**Nichol and Locke, 1999; Bauserman et al., 2016**). Some data regarding Fe availability have been reported from in vitro experiments. **Latunde-Dada et al. (2016)** showed that species like grasshopper (*Sphenarium purpur-ascens*), cricket (*Gryllus bimaculatus*), yellow mealworm (*Tenebrio molitor*), and buffalo worm (*Alphitobius diaperinus*) could be excellent sources of bioavailable Fe. Fe solubility was even significantly higher from the insects than from beef sirloin. Grasshopper, cricket, and mealworms also have significantly higher amounts of available Ca, Cu, Mg, Mn, and Zn than beef.

Despite the benefits resulting from consumption of insects, their acceptance by consumers is highly problematic (**Huis 2013**). Some people consider insects as primitive, disgusting and inferior food, and reject them because of sensory properties, and fear of it (**Caparros Megido et al., 2016; Tan et al., 2016; Hartmann and Siegrist, 2017; Gallen et al., 2019**).

Edible insects in crushed form seems to enjoy much higher acceptability (**Pascucci, 2013; Menozzi et al., 2017; Sogari et al., 2017; Stoops et al., 2017**), especially incorporated into a variety of food products, such as crackers, pasta, baked goods, protein bars, raw bars and cookies. Thus, insect powder (flour) has made its way into the market. Due to its longer shelf life and easier handling, it is also used by consumers at home.

Insect powder is the most frequently made from crushed crickets, specifically the house cricket (*Acheta domesticus*), which appears to be one of the most promising farm insect species for human consumption because of its nutritional profile and breeding advantages (**Collavo et al., 2005; Skotnicka et al., 2021**).

The main objective of this study was to assess the contents of 14 minerals (Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, and Zn) in cricket powders, as well as in bodies of popular insect species available in the Czech Republic, including house cricket (*A. domesticus*), yellow mealworm (*Tenebrio molitor*), desert locust (*Schistocerca gregaria*) and superworm (*Zophobas morio*).

The obtained results deepen our understanding of the nutritional composition of edible insects and their role in human nutrition. The possibility of increasing the dietary intake of frequently deficient elements by including the given insect species into the diet is discussed. Special emphasis is devoted to elements of high nutritional importance such as Fe, Zn, and Ca.

2. Materials and methods

The contents of the tested elements in the samples were determined by means of high-resolution continuum source graphite furnace atomic absorption spectrometry (HR-CS GF-AAS) and flame atomic absorption/ emission spectrometry (F-AAS/AES) after microwave digestion of the samples.

2.1. Samples and sample treatment

A total of 14 samples including commercially available cricket powder ($n = 3$) and farmed insect species: house cricket adult ($n = 3$), yellow mealworm beetle larvae ($n = 3$), desert locust adult ($n = 2$), and superworm larvae ($n = 3$) were used in this study. The samples were purchased from retail supermarkets and pet shops in the south Moravian region (Czech Republic). Prior to analysis, insects were left to starve for two days, then freeze killed, dried in a hot air oven (105 °C, 12 h), and homogenized. Cricket powders were analyzed as received.

In laboratory, all samples were mineralized using an MLS-1200 Mega microwave digestion system (Milestone, Italy). The 250-mg aliquots of each sample were mixed with 4 mL of nitric acid and 0.5 mL of hydrogen peroxide and then digested. Subsequently, the obtained solutions were diluted to 25 mL with MQ water. To ensure the accuracy of the analysis, four certified reference materials, which cover all the investigated elements (SRM 1570a Spinach leaves, INCT-TL-1 Tea leaves, BCR-482 Lichen, and BCR-191 Brown bread) were digested and analyzed together with the samples.

2.2. Determination of elements in digests

The concentrations of elements in the digests were determined using HR-CS GF-AAS (Cd, Co, Cr, Fe, Ni, P, and Pb), F-AAS (Ca, Cu, Mn, Mg, and Zn) and F-AES (K, Na) using ContrAA 800 G (Analytik Jena, Germany) and Unicam Solaar 939 (Cambridge, UK) spectrometers. Measurement conditions were

optimized prior to analysis and trueness of the measurement was checked by means of a set of four abovementioned reference materials. The recoveries obtained were in the range of 90-106 %. See supplementary table SI for detailed information.

2.3. Statistical analyses

The obtained data were statistically analyzed using “R” Statistical Software version 3.4.1 (**R Core Team, 2016**). Since the normality of the data within individual sample groups could not be assumed, nonparametric Kruskal-Wallis test was used to compare the investigated groups.

3. Results and discussion

The determined ranges of mineral contents are listed in **Table 1** (all results can be found in the supplementary table S2). The values are related to dry weight for the reason that European and American consumers accept insects much more willingly in dried form, e.g. as powders or protein bars (**Tan et al., 2015; Hartmann et al., 2018**). The utilization of dried insects for food processing offers advantages such as a longer shelf life, enriched nutrient levels, and easier transport and handling (**Tančinová et al., 2005**). Still, in some African countries insects are commonly consumed fresh, however, direct consumption is neither common nor popular in western countries (**Van Huis, 2016; Jideani and Netshiheni, 2017; Mutungi et al., 2019**).

3.1. Iron content

Cricket powders exhibited the median Fe content of 6.2 mg/100 g which was higher than any of unprocessed edible insect species investigated. Generally, the production of commercial cricket powder involves removing of legs and wings, which, combined with different quality of feed, may explain the difference in Fe contents between unprocessed crickets and cricket powders (**Cricket Flours, 2021**). The same applies to the other elements. Nevertheless, both cricket powders and examined insect species exhibit richer source of Fe than most of common cereals, grains and flours (**Zvěřina et al., 2019; Ertl and Goessler, 2018**).

Table 1 Contents of elements in samples of edible insects (in mg/100 g dry weight).

element	cricket powder (made of <i>Acheta domesticus</i>)	house cricket (<i>A. domesticus</i>)	mealworm (<i>Tenebrio molitor</i>)	desert locust (<i>Schistocerca gregaria</i>)	superworm (<i>Zophobas morio</i>)
Ca	176–254	176–265	66–142	169–190	80–98
Cd	0.002–0.01	0.004–0.006	0.008–0.014	0.003–0.008	0.002–0.003
Co	0.001–0.009	0.001–0.015	0.002–0.008	0.005–0.009	<0.001–0.001
Cr	0.01–0.039	0.013–0.018	0.008–0.023	0.017–0.045	0.012–0.021
Cu	2.1–2.4	1.8–2.9	2.1–2.4	3.5–7.8	1.2–1.5
Fe	5.6–6.4	4.2–5.1	4.5–5	3.6–5	2.9–4.5
K	287–1245	1075–1154	994–1187	651–1131	627–817
Mg	68.2–120.4	84–125	263–335	69–164	95–127
Mn	4.2–5.8	2.5–2.8	0.5–0.9	0.2–0.6	0.5–0.8
Na	157–418	331–413	159–208	151–216	85–111
Ni	0.019–0.064	0.05–0.061	0.046–0.077	0.026–0.103	0.028–0.151
P	989–1233	741–896	798–1054	569–894	410–658
Pb	0.006–0.019	0.01–0.014	0.004–0.01	0.01–0.015	0.002–0.004
Zn	25.4–26.3	16–16.9	11.2–14.1	12.6–17.2	7.9–9.1

Fe contents in unprocessed edible insects did not significantly differ between the four species (Kruskal-Wallis, $p = 0.3$). This finding allows the individual investigated insect species to be considered as a uniform source of Fe.

In comparison with available data, the contents of Fe observed in house cricket (4.2-5.1 mg/100 g) were slightly lower than those reported by **Rumpold and Schlüter (2013)** for the same species (6.27-19.68 mg/100 g). The difference may be attributed to the use of different feed (**Rumpold and Schlüter, 2013; Finke, 2015a, 2015b**). The contents of Fe in yellow mealworm and superworm were consistent with the above-mentioned review.

When compared to values published by Zielińska et al. (2015), the iron contents observed here are slightly higher for yellow mealworm (4.5-5.0 vs. 3.29 ± 0.15 mg/100 g) but lower for desert locust (3.6-5.0 vs 8.38 ± 0.34 mg/100 g). The reason for these different values may be due to the different feeds used.

Some insect species are known to have very high Fe contents; however, such species are not common in this region. For example, *Oecophylla smaragdina* contains 109 mg Fe/100 g in dry weight (Rumpold and Schlüter, 2013) and the termites in Kenya contains 332 mg Fe/100 g. Very high Fe content was reported for the cricket species from Kenya, which contained 1562 mg/100 g (**Ramos-Elorduy et al., 1997**)

3.2. Zinc content

Zn content was the highest in cricket powders with median value of 25.5 mg/100 g. In unprocessed edible insect species, the highest Zn content (16.9 mg/100 g) was observed in house cricket, while the lowest amount (7.9 mg/100 g,) was found in superworm. Other authors found very similar amounts of Zn to our values in the same insect species (7.29-18.64 mg/100 g in dry weight) (**Rumpold and Schlüter, 2013; Zielińska et al., 2015**). The study of **Rumpold and Schlüter (2013)** shows that nymphs of domestic cricket (29.69 mg Zn/100 g in dry weight, measured in one sample) can be an even better source of Zn than adults (15.91-18.64 mg/100 g in dry weight). In our work, only adults of house cricket were used, which are commonly processed for the production of cricket powder.

Zn deficiency occurs in human populations globally, with pregnant women and children under 5 being at the highest risk (Balei et al. 2015). It seems that the cricket powder can greatly promote an adequate dietary supply of Zn. It contains much more Zn than cereals (**Ertl and Goessler, 2018**). Among the species of edible insects, there are even Zn-richer species than the cricket. Such is the case of locust species *Sphenarium histrio* living in Mexico, which contains 78 mg/100 g in dry weight (**Rumpold and Schlüter, 2013**).

3.3. Calcium content

In addition to Fe and Zn, Ca is also an element whose intake is often inadequate in the diet. Its median content in cricket powders was 186 mg/100 g. Measured values of 208 and 180 mg/100 g in house cricket and desert locust, respectively, are in good agreement with reported general Ca contents in the insects (**Rumpold and Schlüter, 2013; Latunde-Dada et al., 2016**). On the other hand, yellow mealworm beetle and superworm contained about half that amount. Unlike Fe, the content of Ca varied significantly between individual species. Therefore, the degree to which diet can be enriched with Ca through the inclusion of insects depends highly on the chosen species. It was shown that Ca

contents in insects can be increased by up to 20 times through the use of Ca- fortified food. However, the apparent increase was composed of residues in the digestive tract rather than Ca incorporated in the insects' body (**Finke, 2004**). This might be an explanation for some of the very high Ca contents reported such as 1290 mg/100 g for house cricket (**Barker et al., 1998**). To eliminate this distortion, insects in this work were left without feed for two days before analysis.

Despite the fact that Ca contents determined here are similar to those reported by studies that proposed insects as an alternative source of Ca, the nutritive significance of such levels is disputable (see chapter Meeting DRV by a single serving of edible insects).

3.4. Potentially toxic elements

The safety of entomophagy is an area which requires extensive research due to the great potential of the practical use of edible insects in the food industry. A risk may arise from the presence of heavy metals due to their ability to accumulate in the insect tissues (**Murefu et al., 2019**). Recently, elevated levels of Cd, Cu, Mn, Ni, Pb, and Zn have been observed in some edible insects (**Handley et al., 2007; Banjo et al., 2010; Greenfield et al., 2014**).

Our data showed that the maximum Cd and Pb contents were 0.014 and 0.019 mg/100 g, respectively. The maximum permitted levels of Cd and Pb in insects has not been officially determined; nevertheless, the contents observed in this work are far below the limits suggested for crustaceans, which are anatomically similar (0.05 mg/100 g). The maximum permitted levels of heavy metals are usually given for foods in fresh weight. Since contents in dry weight that are presented in our study are lower than the recommended values in fresh weight of crustaceans, we can assume that no insect species investigated in our work pose a risk with respect to levels of Cd or Pb contamination (**Commission Regulation, 2006**). The maximum detected levels of Pb in insects also do not exceed the limits of Pb for cereals and cereal products (0.02 mg/100 g) (**EFSA (European Food Safety Authority), 2019**).

3.5. Nutritional significance of a single serving of edible insects in the context of DRV

In this section, content of particularly important elements determined in the samples is compared to that in foodstuffs considered as their good sources. Contents of minerals in the foodstuffs used for comparison were obtained from **USDA database (2019)**. Furthermore, to illustrate the significance of the assessed edible insects as sources of minerals, the amounts of minerals provided in a single portion of dried insect are compared to DRV (Dietary Recommended Values) in **Table 2**. The DRV indicates a daily amount of a nutrient needed to maintain health in an otherwise healthy individual. A portion size of 100 g was chosen since the standard serving size for edible insects has not yet been proposed, and this size portion is also standard on food labels.

Food items such as red meat and offal are considered to be some of the best sources of Fe (**EFSA (European Food Safety Authority), 2015b**) with only 36 g of goose liver or 2 large-sized portions of raw beef (550 g) providing the DRV. The DRV for Fe may be also achieved by consuming the unrealistic amount of 20 egg yolks (provided 1 egg yolk weighs 20 g), 1.5 kg of broccoli, or approximately 240 g of insects such as house cricket, yellow mealworm beetle, and desert locust, or 344 g of superworm.

Foods that contain relatively high amounts of Zn are meat, egg yolks, grains, and legumes (**EFSA (European Food Safety Authority), 2014**). As little as about 57 g of house cricket, or 65 g of yellow

mealworm beetle or desert locust can provide the DRV compared to 200 g of beef, 20 egg yolks, and approximately 290 g raw lentils or wheat whole-grain flour.

According to some studies (**Adámková et al., 2014**), edible insects can be as good a source of Ca as milk; however, to drink 3 glasses of milk may be an easier way of meeting the DRV for Ca than eating 555 g of desert locust, or approximately 1.1 kg of yellow mealworm beetle or superworm. The DRV for Ca can be achieved also by 2 full handfuls of poppy seeds, 140 g of gouda cheese, or approximately 2 kg of broccoli.

For effective Ca absorption in the body, it is also important to ensure an adequate Ca to P ratio, which should be from 1.4:1 to 1.9:1 (**EFSA (European Food Safety Authority), 2015a**). None of our insect samples achieved this ratio. The measured content of P in house cricket and desert locust was four times greater than the respective content of Ca. In superworm it was five times greater, and in samples of yellow mealworm beetles it was as much as eleven times greater. Since other authors also report a low ratio of calcium to phosphorus in insects (**Rumpold and Schlüter, 2013; Tang et al., 2019**), we can infer that calcium in the given insects is difficult to absorb effectively.

In contrast, we found that the intake of Cu, P, and Zn from a 100-g portion of some insect species can even exceed the DRV for these elements.

3.6. Implication of cricket powder for gastronomy

Cricket powder can be used in same way as an ordinary flour, and its properties (medium brown color, and slightly nut- to cereal-like taste and aroma) allow it to be added to meals and foods without being noticed by consumers (**Barton et al., 2020**).

On the other hand, in terms of nutritional composition it is a fundamentally different ingredient. In addition to a more favorable ratio of macronutrients (high amount of protein at the expense of carbohydrates, high dietary fiber, and fat content, especially unsaturated, see **Montowska et al., 2019**), it also contains a richer mineral profile. In comparison with wheat flour, cricket powder contains much more Fe (6.2 vs 3.86 mg/100 g), Zn (25.5 vs. 3.24 mg/100 g), and Ca (186 vs. 38 mg/100 g), also Mn (4.3 vs. 3.56 mg/100 g), K (384 vs. 376 mg/100 g), Cu (2.3 vs. 0.45 mg/100 g), Na (174 vs. 3 mg/100 g), and P (1097 vs. 376 mg/100 g), only content of Mg is lower (79.2 vs. 136 mg/100 g) (median of determined contents vs. **USDA (U.S. Department of Agriculture), 2019**).

Cricket powder is also gluten-free which makes it suitable for people with celiac disease or gluten allergy (**Pauter et al., 2018; Kowaiczewski et al., 2019**). However, the absence of gluten results in slightly different dough properties and requires some practice to learn how to bake with the cricket powder - especially if it is added in large quantities.

Cricket powder may be combined with cereal flours and, thus is used as a partial replacement of common types of flour in various cereal products (muffins, bread, pasta, cookies etc.) to increase their nutritional profile, which is highly desirable. The added proportion of cricket powder in the range of 2-15 % is the most frequently used in the scientific studies (**Pauter et al., 2018; Duda et al., 2019; González et al., 2019; Biro et al., 2020**).

To demonstrate the nutritional consequences, in this work, cricket powder was used as a 10 % flour replacement in recipes for pasta and bread, and as a 50 % replacement in the pancake recipe (**Fig. 1**).

- Pasta recipe (90 g flour, 10 g cricket powder, 1 egg, olive oil and salt) for 1 portion

- Bread recipe (150 g whole-grain flour, 120 g wheat flour, 30 g cricket powder, 1 tsp dried yeast, 1 tsp salt, 1 tsp cumin, 300 mL water)
- Pancake recipe (2 tbsp wheat flour, 2 tbsp cricket powder, 1 medium banana, 1 egg, 60 mL milk) for 1 portion

Of all the minerals, changes of Zn content were the most apparent with an increase ranging from 92 to 386 % in meals. The greatest increase in elements is observed in the pancakes with the highest proportion of cricket powder used: approx. 48 % increase in Ca content, 71 % in Fe and approx. 386 % in Zn (**Table 3**).

Replacing ten percent of the wheat flour with cricket powder is almost indistinguishable in the final taste of the meal. Yet, this enrichment of a common bread recipe increased Zn content by 92 %, Ca by 44 % and Fe by 15 % (**Table 3**). It seems that one third of the DRV for Zn may be achieved by a portion of pancakes.

Table 2 Contribution of a 100-g serving of dried edible insect per day to the DRV of some essential elements.

Element	DRV*		Percentage of DRV provided by a 100 g serving of dried edible insects			
	AI (mg/day)	PRJ (mg/day)	house cricket (<i>Acheta domesticus</i>)	yellow mealworm (<i>Tenebrio molitor</i>)	desert locust (<i>Schistocerca gregaria</i>)	superworm (<i>Zophobas morio</i>)
Ca	–	1000	18–27	7–14	17–19	8–10
Cu	1.6	–	113–181	131–150	219–488	75–94
Fe	–	11	38–46	41–45	33–45	26–41
K	3500	–	31–33	28–31	19–32	18–23
Mg	350	–	24–36	17–96	20–47	27–32
Na	2000	–	17–21	8–11	8–11	5–6
P	550	–	135–163	145–192	104–163	75–120
Zn	–	9.4	170–180	119–150	134–183	84–97

* DRV in mg per adult male, obtained from EFSA's DRVs. The Adequate Intake (AI) was used for Cu, Mg, Na, K, and P. The Population Reference Intake (PRI) was used for Fe, Zn, and Ca (EFSA (European Food Safety Authority), 2019).

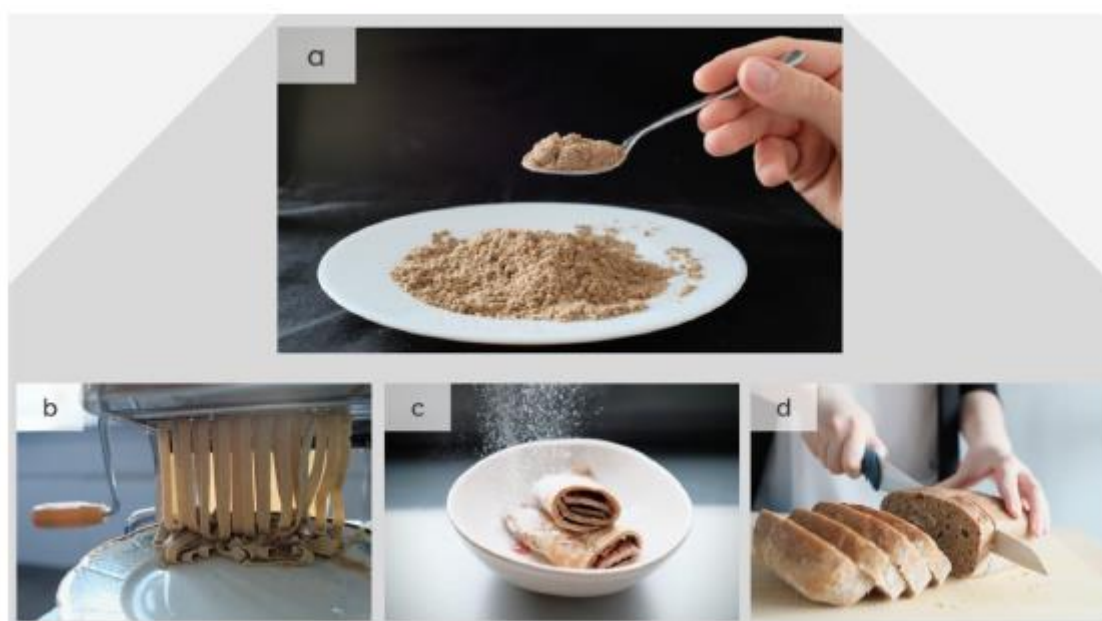


Fig. 1. Cricket flour (a) and the examples of recipes with its addition: b) a pasta, c) pancakes, d) a bread.

Table 3 Changes in the mineral profile of the meals caused by replacing part of the wheat flour in the recipe with cricket powder.

Meal (and portion of wheat flour replaced with cricket powder)	Changes in the contents of minerals in food (mg/100 g) with the addition of cricket powder		
	Fe	Zn	Ca
Pasta (10 %)	1.3 → 1.6	1.4 → 2.9	31.3 → 42.6
Bread (10 %)	3.3 → 3.8	2.5 → 4.8	38.8 → 56.0
Pancakes (50 %)	0.7 → 1.2	0.7 → 3.4	41.7 → 61.9

4. Conclusion

Including edible insects and derived products (e.g., cricket powder) in the human diet can increase dietary variety. Much is known about their high protein content, but also worth noting is their mineral content. Cricket powder can be a simple means of improving the mineral profile of meals, including those plant based. Besides vegetarian diet, it can promote adequate nutrition in people with high nutritional requirements, such as adolescent girls, pregnant women, seniors, and malnourished patients with chronic diseases. The bioavailability of minerals is, however, still in need of investigation if edible insects are to be assessed as reliable sources of such minerals.

References

- Adámková, A., Kouřimská, L., Borkovcová, M., Mlček, J., Bednářová, M., 2014. Calcium in edible insects and its use in human nutrition. *Potravinářstvo* 8 (1), 233-238. <https://doi.org/10.5219/366>.
- Banjo, A.D., Lawal, O.A., Fasunwon, B.T., Alimi, G.O., 2010. Alkali and heavy metal contaminants of some selected edible arthropods in South Western Nigeria. *Am. Eurasian J. Toxicol. Sci.* 2 (1), 25-29.
- Barker, D., Fitzpatrick, M.P., Dierenfeld, E.S., 1998. Nutrient composition of selected whole invertebrates. *Zoo Biol.* 17 (2), 123-134. [https://doi.org/10.1002/\(SICI\)1098-2361N99817:2<123.AID-ZOO7>3.0.CO;2-B](https://doi.org/10.1002/(SICI)1098-2361N99817:2<123.AID-ZOO7>3.0.CO;2-B).
- Barton, A., Richardson, C.D., McSweeney, M.B., 2020. Consumer attitudes toward entomophagy before and after evaluating cricket (*Acheta domesticus*)--based protein powders. *J. Food Sci.* 85 (3), 781-788. <https://doi.org/10.1111/1750-3841.15043>.
- Bauserman, M., Lokangaka, A., Kodondi, K.-K., Gado, J., et al., 2016. Caterpillar cereal as a potential complementary feeding product for infants and young children: nutritional content and acceptability. *Matern. Child Nutr.* 11, 214-220. <https://doi.org/10.1111/mcn.12037>.
- Biró, B., Sipos, M.A., Kovács, A., Bádák-Kerti, K., Pásztor-Huszár, K., Gere, A., 2020. Cricket-enriched oat biscuit: technological analysis and sensory evaluation. *Foods* 9 (11). <https://doi.org/10.3390/foods9111561>.
- Bukkens, S.G., 1997. The nutritional value of edible insects. *Ecol. Food Nutr.* 36, 287-319. <https://doi.org/10.1080/03670244.1997.9991521>.

Caparros Megido, R., Gierts, C., Blecker, C., Brostaux, Y., Haubruge, E., Alábi, T., Francis, F., 2016. Consumer acceptance of insect-based alternative meat products in Western countries. *Food Qual. Prefer.* 52, 237-243. <https://doi.org/10.1016/j.foodqual.2016.05.004>.

Collavo, A., Glew, R.H., Huang, Y.-S., Chuang, L.T., Bosse, R., Paoletti, M.G., 2005. Housecricket Smallscale Farming in Ecological Implications of Minilivestock: Potential of Insects, Rodents, Frogs and Snails. *View Project. Sci. Publ. Enfield, USA.* 515-540.

Commission Regulation, 2006. Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. *Off. J. Eur. Union.* L 364/5.

Cricket Flours, 2021. How to Make Cricket Flour (accessed 07 July 2021). <https://www.cricketflours.com/how-to-make-cricket-flour/>.

Duda, a., Adamczak, J., Chełmińska, P., Juskiewicz, J., Kowalczewski, P., 2019. Quality and Nutritional/Textural properties of durum wheat pasta enriched with cricket powder. *Foods.* 8 (2), 46. <https://doi.org/10.3390/foods8020046>.

EFSA (European Food Safety Authority), 2014. Scientific Opinion on Dietary Reference Values for Zinc. <https://doi.org/10.2903/j.efsa.2014.3844> (accessed 14 November 2020).

EFSA (European Food Safety Authority), 2015a. Scientific Opinion on Dietary Reference Values for Phosphorus. <https://doi.org/10.2903/j.efsa.2015.4185> (accessed 14 November 2020).

EFSA (European Food Safety Authority), 2015b. Scientific Opinion on Dietary Reference Values for Iron. <https://doi.org/10.2903/j.efsa.2015.4254> (accessed 14 November 2020).

EFSA (European Food Safety Authority), 2019. DRV Finder. <https://www.efsa.europa.eu/en/interactive-pages/drvs?fp%C5%99eklada%C4%8Dlid=lwARIBp%C5%99ekIVHFPPqOdkRDw9uKwEGCnli6KHhBAO7mNvhM-BqR5yQ0v5h4dFO7Oc>.

Ertl, K., Goessler, W., 2018. Grains, whole flour, white flour, and some final goods: an elemental comparison. *Eur. Food Res. Technol.* 244, 2065-2075. <https://doi.org/10.1007/s00217-018-3117-1>.

Finke, M.D., 2002. Complete nutrient composition of commercially raised invertebrates used as food for insectivores. *Zoo Biol.* 21, 269-285. <https://doi.org/10.1002/zoo.10031>.

Finke, M.D., 2004. Nutrient content of insects. In: Capinera, J.L. (Ed.), *Encyclopedia of Entomology*. Kluwer Academic, pp. 1563-1575.

Finke, M.D., 2015a. Complete nutrient content of four species of commercially available feeder insects fed enhanced diets during growth. *Zoo Biol.* 34 (6), 554-564. <https://doi.org/10.1002/zoo.21246>.

Finke, M.D., Rojo, S., Roos, N., et al., 2015b. The European Food Safety Authority scientific opinion on a risk profile related to production and consumption of insects as food and feed. *J. Insects Food Feed.* 1 (4), 245-247. <https://doi.org/10.3920/JIFF2015.x006>.

Gallen, C., Pantin-Šohier, G., Peyrat-Guillard, D., 2019. Cognitive acceptance mechanisms of discontinuous food innovations: the case of insects in France. *Rech. Appl. En Mark.* 34 (1), 48-73. <https://doi.org/10.1177/2051570718791785>.

González, C.M., Garzán, R., Roselli, C.M., 2019. Insects as ingredients for bakery goods. A comparison study of *H. Illucens*, *A. domestica* and *T. Molitor* flours. *IFSET.* 51. *Innovations in Food Science and Technology at the Spanish National Research Council (esic)*, pp. 205-210. <https://doi.org/10.1016/j.ifset.2018.03.021>.

Greenfield, R., Akala, N., Van Der Bank, F.H., 2014. Heavy metal concentrations in two populations of Mopane worms (*Imbrasia belina*) in the Kruger National Park pose a potential human health risk. *Bull. Environ. Contam. Toxicol.* 93, 316-321. <https://doi.org/10.1007/s00128-014-1324-4>.

Handley, M.A., Hall, C., Sanford, E., et al., 2007. Globalization, binational communities, and imported food risks: results of an outbreak investigation of lead poisoning in Monterey County, California. *Am J Public Health.* 97 (5), 900-906. <https://doi.org/10.2105/AJPH.2005.074138>.

Hartmann, C., Siegrist, M., 2017. Consumer perception and behaviour regarding sustainable protein consumption: a systematic review. *Trends Food Sci. Technol.* 61, 11-25. <https://doi.org/10.1016/j.tifs.2016.12.006>.

Hartmann, C., Ruby, M.B., Schmidt, P., Siegrist, M., 2018. Brave, health-conscious, and environmentally friendly: positive impressions of insect food product consumers. *Food Qual. Prefer.* 68, 64-71. <https://doi.org/10.1016/j.foodqual.2018.02.001>.

Jideani, A.I.O., Netshiheni, R.K., 2017. Netshiheni Selected edible insects and their products in traditional medicine, food and pharmaceutical industries in Africa: utilisation and prospects. in: Mikkola, H. (Ed.), *Future Foods*. IntechOpen.

Kouřimská, L., Adámková, A., 2016. Review article: nutritional and sensory quality of edible insects. *NFSJ.* 4, 22-26. <https://doi.org/10.1016/j.nfs.2016.07.001>.

Kowalczewski, P., Wálkowiák, L.K., Masewicz, L., Bartczak, O., Lewandowicz, J., Kubiak, P., Baranowska, H.M., 2019. Gluten-free bread with cricket powder—mechanical properties and molecular water dynamics in dough and ready product. *Foods* 8 (7). <https://doi.org/10.3390/foods8070240>.

Latunde-Dada, G.O., Yang, W., Aviles, M.V., 2016. in vitro iron availability from insects and sirloin beef. *J. Agric. Food Chem.* 64 (44), 8420-8424. <https://doi.org/10.1021/acs.jafc.6b03286>.

Manditsera, F.A., Luning, P.A., Fogliano, V., Lákemond, C.M.M., 2019. Effect of domestic cooking methods on protein digestibility and mineral bioaccessibility of wild harvested adult edible insects. *Food Res. int.* 121, 404-411. <https://doi.org/10.1016/j.foodres.2019.03.052>.

Menozi, D., Sogari, G., Veneziani, M., Šimoni, E., Mora, C., 2017. Eating novel foods: an application of the Theory of Planned Behaviour to predict the consumption of an insect-based product. *Food Qual. Prefer.* 59, 27-34. <https://doi.org/10.1016/j.foodqual.2017.02.001>.

MIček, J., Rop, O., Borkovcová, M., Bednářová, M., 2014. A comprehensive look at the possibilities of edible insects as food in Europe—a review. *Pol J. Food Nutr. Sci.* 64 (3), 147-157. <https://doi.org/10.2478/vl0222-012-0099-8>.

Montowska, M., Kowalczewski, P.Ł., Rybicka, i., Fornal, E., 2019. Nutritional value, protein and peptide composition of edible cricket powders. *Food Chem.* 289, 130-138. <https://doi.org/10.1016/j.foodchem.2019.03.062>.

Murefu, T.R., Máček, L., Musundire, R., Manditsera, F.A., 2019. Safety of wild harvested and reared edible insects: A review. *Food Control* 101, 209-224. <https://doi.org/10.1016/j.foodcont.2019.03.003>.

Mutungi, C., Irungu, F.G., Nduko, J., Mutua, F., Affognon, H., Nakimbugwe, D., Ekesi, Š., Fiaboe, K.K.M., 2019. Postharvest processes of edible insects in Africa: a review of processing methods, and the implications for nutrition, safety and new products development. *Crit. Rev. Food Sci. Nutr.* 59 (2), 276-298. <https://doi.org/10.1080/10408398.2017.1365330>.

Nichol, H., Locke, M., 1999. Secreted ferritin subunits are of two kinds in insects molecular cloning of cDNAs encoding two major subunits of secreted ferritin from *Calpodes ethlius*. *Insect Biochem. Mol. Biol.* 29 (11), 999-1013. [https://doi.org/10.1016/S0965-1748\(99\)00076-4](https://doi.org/10.1016/S0965-1748(99)00076-4).

Nowak, V., Persijn, D., Rittenschober, D., Charrondiere, U.R., 2016. Review of food composition data for edible insects. *Food Chem.* 193, 39-46. <https://doi.org/10.1016/j.foodchem.2014.10.114>.

Paoletti, M.G., Dreon, A.L., 2005. Minilivestock, environment, sustainability, and local knowledge disappearance. in: Paoletti, M.G. (Ed.), *Ecological implications of Minilivestock. Potential of insects, Rodents, Frogs and Snails*. Science Publishers Inc., Enfield, pp. 1-18.

Pascucci, S., 2013. information Bias condemning radical food innovators? The case of insect-based products in the Netherlands. *IFAMA* 16 (3), 1-16 (accessed 07 July 2021). <https://www.ifama.org/resources/Documents/vl6i3/Pascucci-Mágistris.pdf>.

Pauter, P., Róžańska, M., Wiza, P., Dworczaś, Š., Grobelna, N., Šarbák, P., Kowalczewski, P., 2018. Effects of the replacement of wheat flour with cricket powder on the characteristics of muffins. *Inst. Food Technol. Plant Origin* 17 (3), 227-233. <https://doi.org/10.17306/J.AFS.2018.0570>.

Payne, C.L.R., Scarborough, P., Rayner, M., Nonaká, K., 2016a. Are edible insects more or less' healthy' than commonly consumed meats? A comparison using two nutrient profiling models developed to combat over- and undernutrition. *Eur. J. Clin. Nutr.* 70 (3), 285-291. <https://doi.org/10.1038/ejcn.2015.149>.

Payne, C.L.R., Nonaká, K., Scarborough, P., Rayner, M., 2016b. A systematic review of nutrient composition data available for twelve commercially available edible insects, and comparison with reference values. *Trends Food Sci. Technol.* 47, 69-77. <https://doi.org/10.1016/j.tifs.2015.10.012>.

Persistence Market Research, 2018. Edible insects Market: Global Analysis, Size, Share, Value, Demand, Market Growth by 2024. <https://www.persistencemarketresearch.com/market-research/edible-insects-market.asp>.

Pimentel, D., 2004. Livestock production and energy use. in: Cleveland, C.J. (Ed.), *Encyclopedia of Energy*. Elsevier Science, pp. 671-676.

Pimentel, D., Dritschilo, W., Krummel, J., Kutzman, J., 1975. Energy and land constraints in food protein production. *Science* 190 (42), 754-761. <https://doi.org/10.1126/science.190.4216.754>.

R Core Team, 2016. R: A Language and Environment for Statistical Computing. Vienna, Austria. Available online at: <https://www.R-project.org/> (accessed 7 March 2020).

Ramos-Elorduy, J., Moreno, J.M.P., Prado, E.E., et al., 1997. Nutritional value of edible insects from the state of Oaxaca. Mexico. *J Food Compost Anal.* 10 (2), 142-157. <https://doi.org/10.1006/jfca.1997.0530>.

Regulation (EU), 2018. Commission implementing Regulation (EU) 2018/1023 of 23 July 2018 correcting implementing Regulation (EU) 2017/2470 establishing the Union list of novel foods. *Off. J. Eur. Union*, L 187, 1-133.

Rumpold, B.A., Šchluter, O.K., 2013. Nutritional composition and safety aspects of edible insects. *Mol. Nutr. Food Res.* 57 (5), 802-823. <https://doi.org/10.1002/mnfr.201200735>.

Skotnicka, M., Karwowska, K., Kłobukowski, F., Borkowska, A., Pieszko, M., 2021. Possibilities of the Development of Edible Insect-Based Foods in Europe. *Foods*. <https://doi.org/10.3390/foods10040766>.

Sogari, G., Menozzi, D., Mora, C., 2017. Exploring young foodies' knowledge and attitude regarding entomophagy: a qualitative study in Italy. *Int. J. Gastron. Food Sci.* 7, 16-19. <https://doi.org/10.1016/j.ijgfs.2016.12.002>.

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, et al., 2006. *Livestock's Long Shadow, Environmental issues and Options*. FAO, Rome, Italy. Available online at: <http://www.fao.org/3/a0701e/a0701e00.pdf> (accessed 10 November 2020).

Stoops, J., Vandeweyer, D., Crauwels, Š., Verreth, C., Boeckx, H., Van Der Borght, M., Claes, J., Lievens, B., Van Campenhout, L., 2017. Minced meat-like products from mealworm larvae (*Tenebrio molitor* and *Alphitobius diaperinus*): microbial dynamics during production and storage. *IFSET* 41, 1-9. <https://doi.org/10.1016/j.ifset.2017.02.001>.

Tan, H.S.G., Fischer, A.R.H., Tinchan, P., Štieger, M., Šteenbekkers, L.P.A., Van Trijp, H. C.M., 2015. Insects as food: exploring cultural exposure and individual experience as determinants of acceptance. *Food Qual. Prefer.* 42, 78-89. <https://doi.org/10.1016/j.foodqual.2015.01.013>.

Tan, H.S.G., Fischer, A.R.H., Van Trijp, H.C.M., Štieger, M., 2016. Tasty but nasty? Exploring the role of sensory-liking and food appropriateness in the willingness to eat unusual novel foods like insects. *Food Qual. Prefer.* 48, 293-302. <https://doi.org/10.1016/j.foodqual.2015.11.001>.

Tančinová, D., Maková, J., Feišćiová, S., Kačániová, M., Kmet, V., 2005. *Mikrobiológia Potravín*, First ed. Slovenská Poľnohospodárska Univerzita, Nitra.

Tang, C., Yang, D., Liao, H., et al., 2019. Edible insects as a food source: a review. *Food Prod Process and Nutr.* 1 (8) <https://doi.org/10.1186/s43014-019-0008-1>.

USDA (U.S. Department of Agriculture), 2019. FoodData Central Search Results (accessed 18 November 2020). <https://fdc.nal.usda.gov/index.html>.

Van Huis, A., 2016. Edible insects are the future? *Proc. Nutr. Soc.* 75 (3), 294-305. <https://doi.org/10.1017/S0029665116000069>.

Van Huis, A., Van itterbeeck, J., Klunder, H., Mertens, et al., 2013. *Edible insects: Future Prospects for Food and Feed Security*. FAO Forestry paper 171, Rome, Italy. Available online at: <http://www.fao.org/3/i3253e/i3253e.pdf> (accessed 10 November 2020).

Whistler, R.L., 1993. Chitin. in: Whistler, R.L., Bemiller, J.N. (Eds.), *Industrial Gums: Polysaccharides and Their Derivatives*. Academic Press, pp. 601-604.

Zielińska, E., Baraniak, B., Karas, M., Jakubczyk, A., Rybczyńska, A.K., 2015. Selected species of edible insects as a source of nutrient composition. *Food Res. Int.* 77, 460-466. <https://doi.org/10.1016/j.foodres.2015.09.008>.

Zvěřina, O., Kuta, J., Coufalík, P., Kosečková, P., Komárek, J., 2019. Simultaneous determination of cadmium and iron in different kinds of cereal flakes using high-resolution continuum source atomic absorption spectrometry. *Food Chem.* 298 <https://doi.org/10.1016/j.foodchem.2019.125084>.