

Sensory evaluation and acceptance Of food made of edible insects

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ABSTRACT

This paper discusses the sensory analysis of food enriched with selected edible insect species which are labelled as a novel food – house cricket (*Acheta domestica*) and mealworm (*Tenebrio molitor*). Energy bars of two different compositions with the addition of cricket flour and puff pastry bars sprinkled with the whole roasted mealworm larvae were evaluated by consumer tests performed via a questionnaire survey. Respondents represented both men and women in equal numbers and included consumers with the experience of the sensory analysis and edible insects to ensure accurate results. Sensory analyses revealed that respondents associated their tastes with already known flavors (salty, sweet, bitter, fish, French fries, chicken, and mushrooms). The most common answer from respondents was a salty taste, followed by a sweet taste. There were also unusual comparisons such as pine seeds. Consumers' positive attitude to these energy bars has been registered which shows that the Czech consumer accepts edible insects in a suitable form as a novel food and possible part of the food basket.

Keywords: edible insect; *Tenebrio molitor*; *Acheta domestica*; sensory analysis

INTRODUCTION

Entomophagy is a practice of edible insect consumption (Imathiu, 2020). The origin of this word comes from Greece, where έντομον éntomon means “insects” and φαγειν phagein is translated as “to eat” (Kouřimská and Adámková, 2016).

Sensory properties comprise an important criterion for edible insect consumption (Borkovcová et al., 2009; Adámek et al., 2017). In western countries, entomophagy is often associated with dirt and poverty, thus being considered unacceptable (Looy, Dunkel and Wood, 2014). Many people disregard insects and they neglect its high nutritive value (Siemianowska et al., 2013). Existing significant prejudices closely connect with a disgust factor representing a major repulsive force that is formed in the child age before 6 or 7 years. In contrast, an edible insect has been consumed in other cultures in Africa, Latin America, Asia (Hanboonsong, 2010; Raheem et al., 2019) and Australia (Siemianowska et al., 2013). There are approximately two billion people in 113 countries consuming edible insects (Lucas et al., 2020). Recently, around 2000 species of edible insects have been registered (Megido et al., 2018). Countries with a common entomophagy practice include Zimbabwe, Japan (Raheem et al., 2019), Thailand with more than 150 edible insect species (Imathiu, 2020), and Mexico with approximately 550 species of edible insect consumed (Siemianowska et

al., 2013). Consuming edible insect is also supported by the fossils (Kouřimská and Adámková, 2016). Technologies of insect mass rearing have been accepted in some countries, such as Holland, Denmark, Belgium, Kenya, and Vietnam (Imathiu, 2020). In China, where entomophagy is practiced for more than 3,000 years (Lucas et al., 2020), edible insect also gains the role of a food ingredient and is seen as a suitable alternative to further kinds of meat (Kröncke et al., 2018).

The insect may be consumed indirectly in a form of extracts or products, such as honey, wax, pollen, and dyes (Lucas et al., 2020).

The potential of edible insects has been growing due to positive environmental impacts (Dossey, Morales-Ramos, and Rojas, 2016). The rearing of edible insects requires less water and space if compared to other livestock. What is more, the amount of produced greenhouse gas is considerably lower (Lucas et al., 2020). Another advantage of growing an edible insect is its high reproduction rate (Imathiu, 2020). Apart from these significant benefits, edible insect as a part of a balanced diet could be a potential source of adequate food supplies due to its high feed conversion rate (Belluco et al., 2013; Van Huis et al., 2013). Furthermore, according to studies, edible insect species provide great nutritional values as they are an excellent source of protein, fat, vitamins as well as minerals (MacEville, 2000; Van Huis et al., 2013). Several

conditions can change the nutritional value of edible insects, such as the environmental conditions or different processes of heat treatment (De Castro et al., 2018). The edible insect could be eaten in a raw form or could be processed by roasting, frying, or boiling (Imathiu, 2020). Interestingly, frying may even improve the sensory quality of insects due to aromatic compounds, attractive colors, crust, and texture. Its hygienic quality may be enhanced by a cooking process thanks to the inactivation of possibly present pathogenic microorganisms (Megido et al., 2018). Unfortunately, heating processes could affect nutritional values as well (Montowska et al., 2019) due to the processes including proteolysis, lipolysis, and lipid oxidation. (Megido et al., 2018).

A prediction of a significant increase in edible insects on the global market is expected to reach 710 million dollars (Roncolini et al., 2020). Mealworm larvae (*Tenebrio molitor*) and crickets (*Acheta domesticus*) are the species most commonly farmed in Europe. What is more, they are considered to be the most promising in the food and feed industry (Imathiu, 2020).

Crickets (*Acheta domesticus*) contain a substantial amount of all-important constituents – proteins, fats, vitamins, and minerals (Montowska et al., 2019).

Based on a questionnaire created by Bednářová et al. (2013), the mealworm was evaluated as one of the most acceptable species for consumption in the Czech Republic. The field cricket was also assessed positively; however, some respondents dislike the feeling of biting into the soft insect body. Their opinion was influenced by the psychological aspect of considering cricket as the food of the poor. Furthermore, European consumers can be divided into two groups – one group prefers the possibility of consuming food with proper visibility of the larvae, while the latter prefers to consume insects in a hidden form (Adámek et al., 2018). This way, the texture of the insect is not easily perceptible. Edible insects, particularly adult specimens, are partly composed of the exoskeleton causing the crunchiness during the consumption influencing the tactile and auditory effect resulting in, along with the chewing, a pleasant feeling similar to the consumption of pretzels, cookies, or other various durable pastry (Ramos-Elorduy, 1998). A beneficial high content of chitin in the exoskeleton should be emphasized (Aguilar-Miranda et al., 2002; Mlček et al., 2014). However, the human body can digest soft larvae after molting because their exoskeletons are not hardened yet (Borkovcová et al., 2009). For this reason, the mealworm larvae were examined in this study.

The taste of the insect could be very diverse. It depends on many factors, such as the environment and the feed including fruits, vegetables, pastries, potatoes, rice, or grass. During the culinary treatment, insect absorbs different flavors of other ingredients which were proved as early as in 1971 by Smith et al. (1971). What is more, if the insect is processed with spices, it will obtain a new flavor and the original taste will be weakened. If it is washed before the consumption, which is not recommended by Ramos-Elorduy (1998) due to the food safety point of view (Bednářová et al., 2010), it will provide hardly any flavor since the pheromones on the insect surface are rinsed away. That is why to ensure full and rich taste it is necessary to serve

insect alive. Due to the health and safety considerations, it is recommended to allow the insect to starve for at least 12 hours. This precaution is recommended particularly for grasshoppers, caterpillars, and beetle larvae (Ramos-Elorduy et al., 1997).

This work aimed to explore the attitude of the general public towards entomophagy in the Czech Republic employing a questionnaire and to evaluate the sensory properties of selected food enriched with the edible insect.

Scientific hypothesis

Food enriched with edible insects is acceptable for consumers in the Czech Republic.

MATERIAL AND METHODOLOGY

Material for sensory analysis

Two species of edible insects were selected for the sensory analysis – mealworm (*Tenebrio molitor*) and house cricket (*Acheta domesticus*). Specimens of mealworm (*Tenebrio molitor*) were purchased in a pet shop and left to starve for 48 hours, killed with boiling water (100 °C), and dried at 105 °C. Subsequently, the insect was sprinkled on the puff pastry bars which were examined in the sensory analysis (Figure 1).

House cricket (*Acheta domesticus*) was sensory evaluated in a form of cricket flour. The sample of cricket flour was used in energy bars. Respondents were provided with two kinds of bars. Sample A contained dates, cricket flour, pineapple, cashew, coconut, psyllium, and lemon peel. Sample B included dates, cricket flour, cocoa powder, cashew, psyllium, and orange peel. Bars were cut into dices, spiked with toothpicks, and offered to the respondents for evaluation.

Survey methodology

Samples were subjected to the sensory analysis and evaluated using a questionnaire. In the first part of the research, the samples of mealworm (*Tenebrio molitor*) were evaluated focusing on the taste. The short form of the questionnaire, designed especially for the wide public, contained mainly questions about the respondent (age, gender) and the taste of insects. Respondents were asked to specify the taste of the sample. Thirty-two respondents participated in the first survey and 53% of them have already experienced food sensory analysis under the laboratory conditions. 25 respondents participated in the second survey with only 40% having the experience of the food sensory analysis.

Bars containing cricket flour were examined in the second part of the experiment using the third questionnaire. This survey was attended by 42 respondents, of which 59% were women and 40% were men. Participants in the lecture were provided with two samples of bars (samples A and B) and forms to evaluate the taste. The respondents were asked to evaluate the pleasantness of both samples by using an ordinal score scale from 1 (excellent taste) to 5 (annoying taste).



Figure 1 Puff pastry bars sprinkled with mealworm (photo Jan Gajdošík).

Statistical analysis

The data were analyzed using Excel 2013 (Microsoft Corporation, USA) and STATISTICA CZ version 12 (StatSoft, Inc., USA), and the results were expressed by mean ± standard error.

Considering cricket flour bars, the results were evaluated using a paired t-test to analyze differences between the means of the evaluation of samples A and B.

The dependency of the evaluation on the gender was evaluated using the χ^2 test which was applied to map differences of preferences between genders. For this test, a modified table was used with the preference marked as follows:

A = evaluator scored a better rating for the sample A,
 B = evaluator scored a better rating for the sample B,
 O = both samples gained the same score from the evaluator.

Puff pastry bars sprinkled with the mealworm larvae were evaluated by the percentage of the taste expressed by the respondent to the total number of answers.

RESULTS AND DISCUSSION

Puff pastry bars sprinkled with mealworm

During the first part of the sensory analysis, a questionnaire survey was used to evaluate samples of mealworm on puff pastry bars. In this first survey, the most significant amount of 31% of respondents described the taste as salty. Other respondents described the taste as sweet (almost nutty) (18.8%), which was the second most selected answer. A similar number of respondents tasted it as the whole grain bread (12.5%) and fish (12.5%). A slightly lower number of respondents opted for the taste of the fried potatoes (9.4%). A small percentage of respondents described the taste as similar to pine seeds, chicken, bitter or other. None of the respondents considered the taste like sour, fatback with skin, mushrooms, apples, raw corn caviar, or herring. A percentage representation of individual flavors is shown in Figure 2.

The results of the second part of the survey are depicted in Figure 3. Most respondents agreed on the option of the sweet taste (24%) and whole grain bread taste (24%).

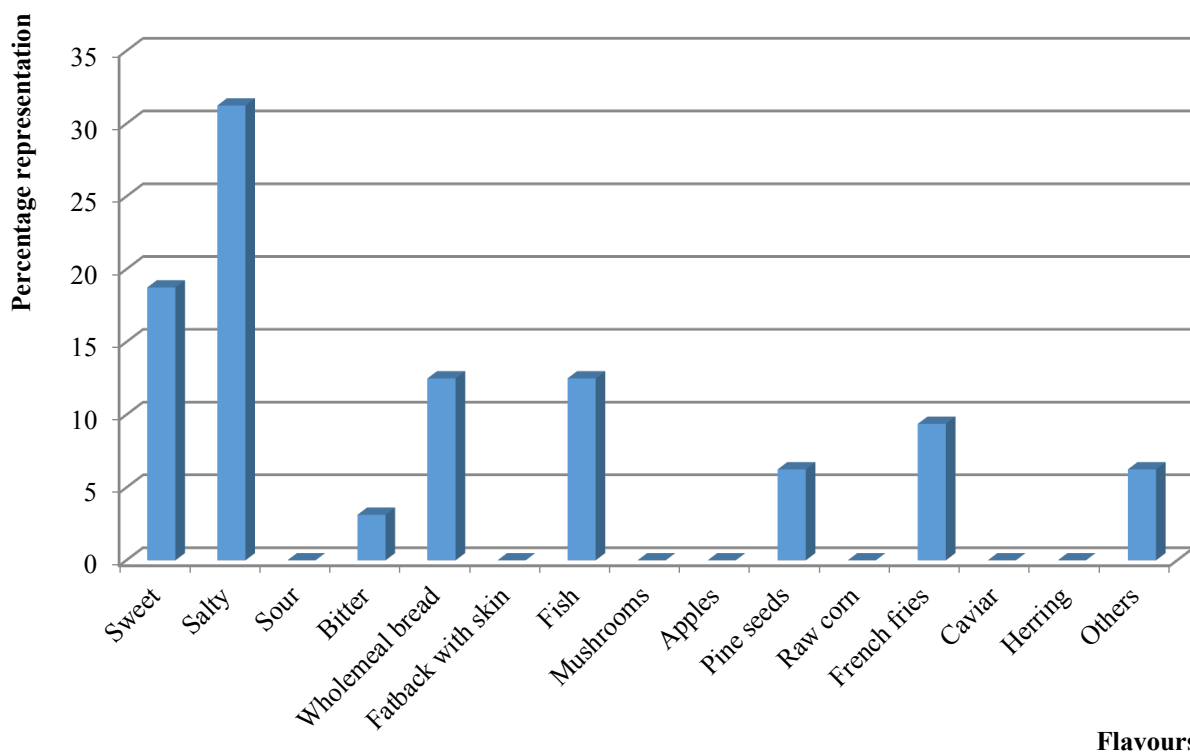


Figure 2 Percentage representation of individual flavours of mealworm samples on puff pastry bars in the survey no.1.

A slightly lower number of respondents (20%) selected salty taste and 16% of respondents described the taste as bitter; the taste was poorly represented in the previous survey. The taste of the pine seeds was selected by 8% of respondents, the option “other” was selected only by one respondent who described the taste as similar to chicken. These results are following the study by **Ramos-Elorduy (1998)** who states that the taste of mealworm (*Tenebrio molitor*) is similar to the taste of the whole grain bread.

There were some similarities in the descriptions of the tastes of both samples – in both cases, the participants selected sweet and salty flavor and the taste of the wholemeal bread and pine seeds. The second sample was characterized by the increase in the frequency of the selection of the sweet and bitter taste and the taste of the wholemeal bread. The flavors of fish and French fries were described only in the first sample. The options for the sour taste and the taste of mushrooms, apples, raw corn, or caviar were not selected by any participant during the analyses.

The edible insect is a highly popular delicacy, especially for its sensory properties (**Borkovcová et al., 2009**). The flavor of insects varies from species to species, and it is affected by pheromones, the environment where insects live, and the feed they eat. **Ramos-Elorduy (1998)** stated a range of flavors from fishy to wheat bread in the case of major classes of edible insects, (adopted from **Mishyna, Chen and Benjamin, (2020)**). Generally, mealworms aroma is stated as nutty or whole wheat bread (**Ramos-Elorduy, 1998; Capponi, 2016; Elhassan et al., 2019**). **Roncolini et al. (2019)** further specify that larvae fed flour or cereal bran have a characteristic sweet, almost nutty flavor, and a nutty, cocoa smell. In contrast, larvae which were as fed grass crickets have a strong crustacean-like, cooked legume-like, and earthy aroma.

The sweet flavor is in accordance with the results of this study because the producer fed the larvae with cereal bran. It has been assumed that the high value of the salty flavor is due to the dough on which the larvae were sprinkled.

Energy bars enriched with cricket flour

In the sensory evaluation of energy bars with the addition of cricket flour, two samples were examined. Sample A containing dates, cricket flour, pineapple, cashew, coconut, psyllium, and lemon peel, and sample B containing dates, cricket flour, cocoa powder, cashew, psyllium, and orange peel. There was no statistical difference between the results of each sample ($p > 0.05$). Furthermore, the results have shown a positive evaluation of both samples which approaches the overall average score 2 as can be seen in Figure 4.

Elhassan et al. (2019) described the flavor of crickets as umami, popcorn, chicken, mild, or creamy. On the other hand, **Capponi (2016)** characterized the flavor of cricket as fishy.

According to the results, the influence of gender on the sample evaluation has not been statistically significant ($p > 0.05$) for any of the samples. **Table 1** shows a small but statistically not significant difference ($p > 0.05$) as women preferred sample A from B, while men preferred B. The reason may be the content of cocoa powder in sample B which women like more than men, e.g. in the form of chocolate candies (**Kozelová et al., 2014**).

In Hungary people who plan to eat less meat or who are looking for new food choice expect to eat edible insects as a substitute. In the study was also noticed that women have bigger neophobia than men (**Gere et al., 2017**).

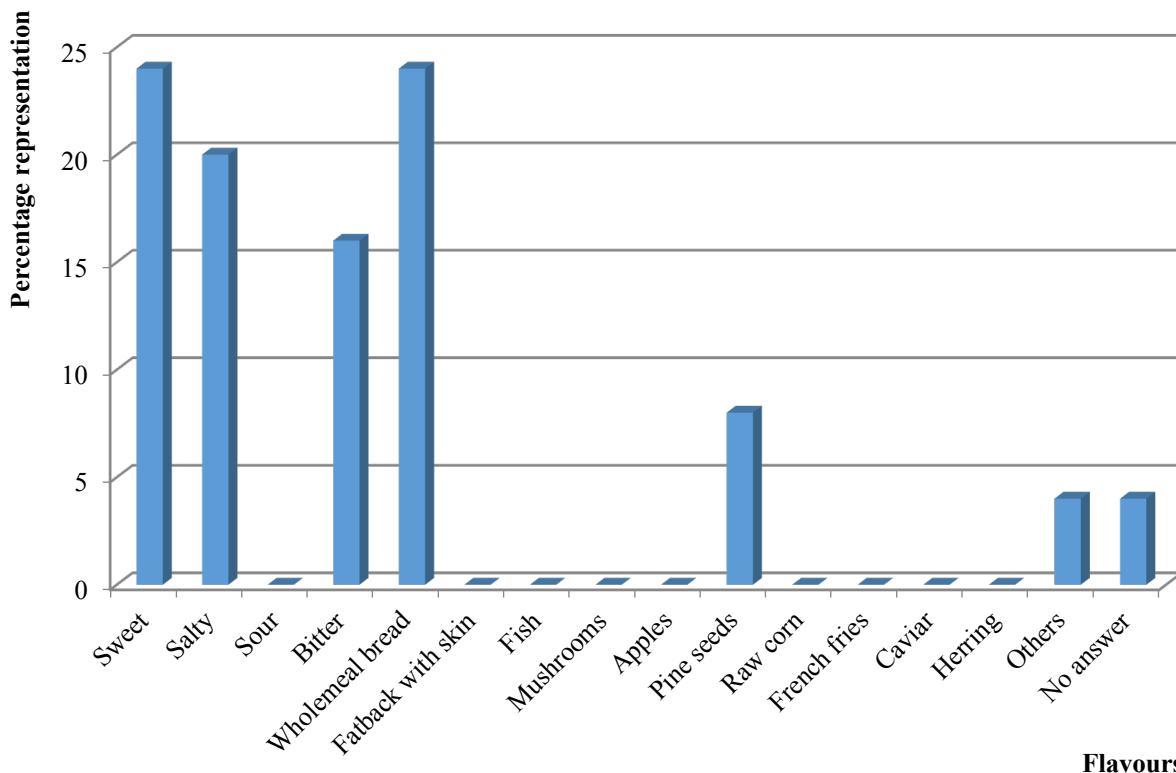


Figure 3 Percentage representation of individual flavours of for mealworm samples on puff pastry bars in the survey no. 2.

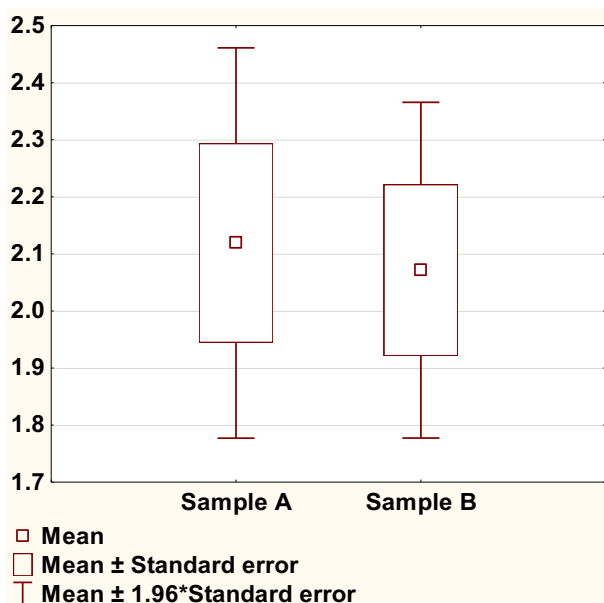


Figure 4 Sensory evaluation of the pleasantness of taste for energy bars enriched with cricket flour in the questionnaire survey no. 3. Note: Sample A – dates, cricket flour, pineapple, cashew, coconut, psyllium and lemon peel; Sample B – dates, cricket flour, cocoa powder, cashew, psyllium and orange peel.

Table 1 Differences of gender preferences for two samples of energy bars enriched with cricket flour in the questionnaire survey no. 3.

Gender	Preferences			
	Sample A (%)	Sample B (%)	Both samples (%)	Total (%)
Woman	40	48	12	100
Man	47	41	12	100
χ^2 test	0.21	0.16	0.00	0.38

Note: 1) Preferences: A = better rating for the sample A, B = better rating for the sample B; 2) Critical value of tested criterium χ^2 for significance level 0.05 and 2 degrees of freedom was 5.991.

The study **Megido et al. (2013)**, which was focused on Belgian consumers, found out the people seemed to be willing to eat and cook insects in the future when it is connected with familiar flavors.

The positive result about the consumption of eating insect-containing products in the future is positively accepted by people in Italy and a slightly higher number of males were open to the idea of a product as an alternative source of protein (**Sogari, Menozzi and Mora, 2017**). In the USA or India are people considering trying to eat some form of insect food and at the same time, men are more inclined to this idea (**Ruby, Rozin and Chan, 2015**).

On the other hand, in Germany is still a prevalence of skepticism towards the consumption of edible insects. The acceptance is similar between both genders if the insect is in an invisible form (**Orsi et al., 2019**). In the study, **Hartmann et al. (2015)** were examined the acceptance of edible insect in a comparison between Germany and China

without noticeable differences between males and females. A similar study focused on the acceptance of edible insect was the comparison of people from Korea and Ethiopia, where was the acceptance of men higher than women in both studied nations (**Ghosh et al., 2020**). Another research was done in a Danish college where the respondents were females. Even though in other studies males are more open to eating edible insects than females, in this research 81% of respondents (only females) tasted the mealworms (**Jensen and Lieberoth, 2018**).

In the study by **Tuccillo et al. (2020)** and **Laureati et al. (2016)** was found that men are more open to entomophagy than women. The same result was mentioned in **Woolf et al. (2019)** where was investigated the opinion of consumption of insect-containing food. Positive willing to trying of insects as food among Dutch consumers were young males, who tried it before (**Tan, van den Berg, and Stieger, 2016**). **Verbeke (2015)** calculated that the predicted acceptance of edible insects as a substitute for meat is 12.8 % for men and 6.3 % for women.

Megido et al. (2016) examined the acceptance of hybrid insect-based burgers where men were more open to eating burgers that contain edible insects.

The interest of consumption of edible insects in products is being investigated by **Gmuer et al. (2016)**, **Le Goff and Delarue (2017)**, or **Hartmann and Siegrist (2016)** where the results were slightly positive. The higher acceptance of edible insects by males when females are mentioned in the study by **Verneau et al. (2016)** where the experiment was held in Denmark and Italy.

Edible insects and consumers in the Czech Republic

During the process of preparation, such as applying the boiling water and cooking edible insects, the original aroma is often removed and the insect acquires the smell and taste of other present ingredients (**Ramos-Elorduy, 1998**). This could be the reason why the respondents also reported the salty taste of the sticks sprinkled with larvae of mealworms and the hazelnut taste was suppressed. Concerning energy bars enriched with the cricket flour, the flavor of the cricket flour was significantly suppressed by the fruit ingredients. Although the customer in the Czech Republic is currently sufficiently informed about edible insects from festivals, TV shows, or magazine articles, the difference between the perceived tastes of edible insects in the visible and hidden form was obvious. The invisible form (energy bars) was accepted without any problems by both men and women even though the respondents had been informed in advance about the flour of edible insects in the bars.

When evaluating the visible form (puff pastry bars sprinkled with mealworm), the initial hesitation was apparent and the male respondents overcame that faster. After the first tasting, the respondents showed no more hesitation to test another sample. This could stem from the above-mentioned suppression of insect flavor. Therefore, it is possible to conquer the initial fear to consume edible insects and to consider them as an interesting and acceptable novel constituent of the diet.

CONCLUSION

This study has confirmed a positive evaluation of selected food with the addition of edible insect employing a questionnaire survey of the general public in the Czech Republic. It has been proved that people welcome the opportunity to taste the samples of edible insects and do not exclude the possibility of conscious eating of the edible insect in the future. Regarding the conscious consumption of visible mealworm larvae on the puff pastry bars, the respondents associated their taste with known flavors of salty, sweet, and chicken, which may lead to further improvement in the attitude towards this commodity. Considering the examination of energy bars enriched with the cricket flour, both samples were positively evaluated. No statistically significant difference has been found between these two samples. Therefore, the results have shown that consumers in the Czech Republic are inclined to consume edible insect products, particularly if they can select the preferable form of the product and the included species.

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