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EDIBLE INSECTS – SPECIES SUITABLE FOR ENTOMOPHAGY UNDER CONDITION OF CZECH REPUBLIC

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Abstract

BEDNÁŘOVÁ MARTINA, BORKOVCOVÁ MARIE, MLČEK JIŘÍ, ROP OTAKAR, ZEMAN LADISLAV: *Edible insects – species suitable for entomophagy under condition of Czech Republic.* Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 2013, LXI, No. 3, pp. 587–593

Since 2002, when the first lecture on entomophagy took place at Mendel University in Brno, till today, participants of these educational lectures were asked to fill questionnaires in order to evaluate interest in entomophagy in Czech Republic and pick suitable species. Analyses of nutritional value of selected species were also performed during this time. The questionnaire was divided into several parts – suitable species, sensory properties, difficulty of breeding and processing and respondents own attitude to the consumption of insect species. For the purpose of this study the questionnaire was evaluated using the semantic differential, so to create a comprehensive picture of each insect species. Based on evaluation of more than 5,000 questionnaires, certain developmental stages of seven species of insect were selected for further evaluation: *Tenebrio molitor* (TM) larvae, *Zophobas morio* (ZM) larvae, *Gryllus assimillis* (GA) nymphs, *Locusta migratoria* (LM) nymphs, *Galleria mellonella* (GM) larvae, *Bombyx mori* (BM) Pupa, *Apis mellifera* (AM) bee brood, while cockroaches were completely excluded for use in entomophagy. Although they are easy to breed and are available all year-round, consumers showed relatively great disgust. For all of these species, basic nutritional values were analysed, as well as content of amino acids and fatty acids. All parameters were statistically evaluated using ANOVA-1. Each species appears to be suitable for entomophagy for a different reason. Generally speaking, AM, TM and GA were best accepted considering the sensory aspect, nutritional values are interesting especially in BM and GM and TM wins with simplicity of its breeding.

Tenebrio molitor, *Zophobas morio*, *Gryllus assimillis*, *Locusta migratoria*, *Schistocerca gregaria*, *Galleria mellonella*, *Bombyx mori*, bee brood, nutritional value, preference of entomophagous people

Entomophagy gains more and more interest worldwide, not only in countries with historically long-term consumption of insects, such as Mexico (Ramos-Elorduy, 2009B; Acuña *et al.*, 2011), Japan (Nonaka, 2009), China (Chen *et al.*, 2009) and many African countries, but also in Europe (DeFoliart, 1992; Oonincx and DeBoer, 2012). There the usual food sources are sufficient, but Brussels has already sounded voices to support the development of entomophagy within the European Union. At the meeting of FAO in April 2012, strategy was created to promote global consumption of insects due to the many positives resulting from this consumption, not only as a source of essential nutrients (Premalatha *et al.*, 2011; FAO, 2012), but also as a functional food (Wattanathorn *et al.*, 2012) and the possibility to contribute to sustainable life on Earth (DeFoliart, 1992; DeFoliart, 1995; DeFoliart, 1997; Ramos-Elorduy, 2009A; Yen, 2009). Europe still sees entomophagy as the food associated with the past of this continent. Insects are also considered unhygienic harbors of diseases and "starvation" food (DeFoliart, 1999). However, in the light of new research, when some species are examined and evaluated (considering their nutritional qualities and ease of breeding) as very suitable for the diet of astronauts or residents of satellite towns in Earth orbit (Katayama *et al.*, 2008), European perception of insects is changing (Rumpold and Schlüter, 2012). This trend can be observed also in the Czech Republic (Borkovcová *et al.*, 2009). Due to the growing interest in entomophagy in the Czech Republic the aim of this work was to (based on many years of experience and the latest findings): suggest the most suitable species of insects for entomophagy in the Czech Republic, both in terms of nutritional value and acceptability to consumers, year-round availability in the market and difficulty of breeding.

MATERIALS AND METHODS

Material: All insects used in this work were obtained by purchasing from companies or institutions in Czech Republic, which already have long experience with their breeding. Caterpillars of BM and GM were purchased from farms at Masaryk University in Brno. Bee brood was purchased from the company Přidal Brno and all other species from the company Frýželka Brno.

Preparation of insect samples for analysis: Caterpillars of GM and BM were purchased alive and stored in plastic containers without food in laboratory conditions (temperature 22 °C, humidity 42%). In case of GM, individuals who entered the post feeding phase and were leaving the containers to create pupae were gradually removed from the containers. These individuals are emptied and reach the largest size, which is optimal state from the entomophagy perspective. Collected individuals were transferred to the freezer, where they were stored and later used for nutritional analyses and cooking. BM caterpillars were kept in containers until they created pupae. Pupae were frozen immediately and gradually used similarly as GM caterpillars. Larvae of TM and ZM and nymphs of GA and LM were purchased alive and left two days without food to starve. Larvae and nymphs were subsequently stored in freezers. Bee brood was taken from the breeder already frozen. Larvae and pupae were removed from the honeycombs using tweezers before analysing.

Analysis: Determination of elements' content was performed on Varian SPECTRA AA 300. Methodics of the samples' mineralisation, conditions for determination of the elements and results' validation was stated by Soxhlet (fatty acids) and Kjehldal (amino acids) methods.

Statistical analysis: Respondent were at first submitted questionnaires related to the selection of appropriate species of insects, age of the respondents, education and their experience with entomophagy. For the 7 insect species with best results, another questionnaire was compiled to evaluate subjective perception of the species, which included questions about the sensory properties of selected insect species (5 questions), difficulty of breeding and processing/cooking (4 questions) and the respondent's own attitude to the consumption of insect (3 questions). Nutritional values for 7 selected insect species were statistically evaluated using ANOVA1 for each variable standard deviation and Tukey's HSD test were calculated. Questionnaires were evaluated using semantic differential.

RESULTS AND DISCUSSION

Selection of insect species suitable for entomophagy in the Czech Republic

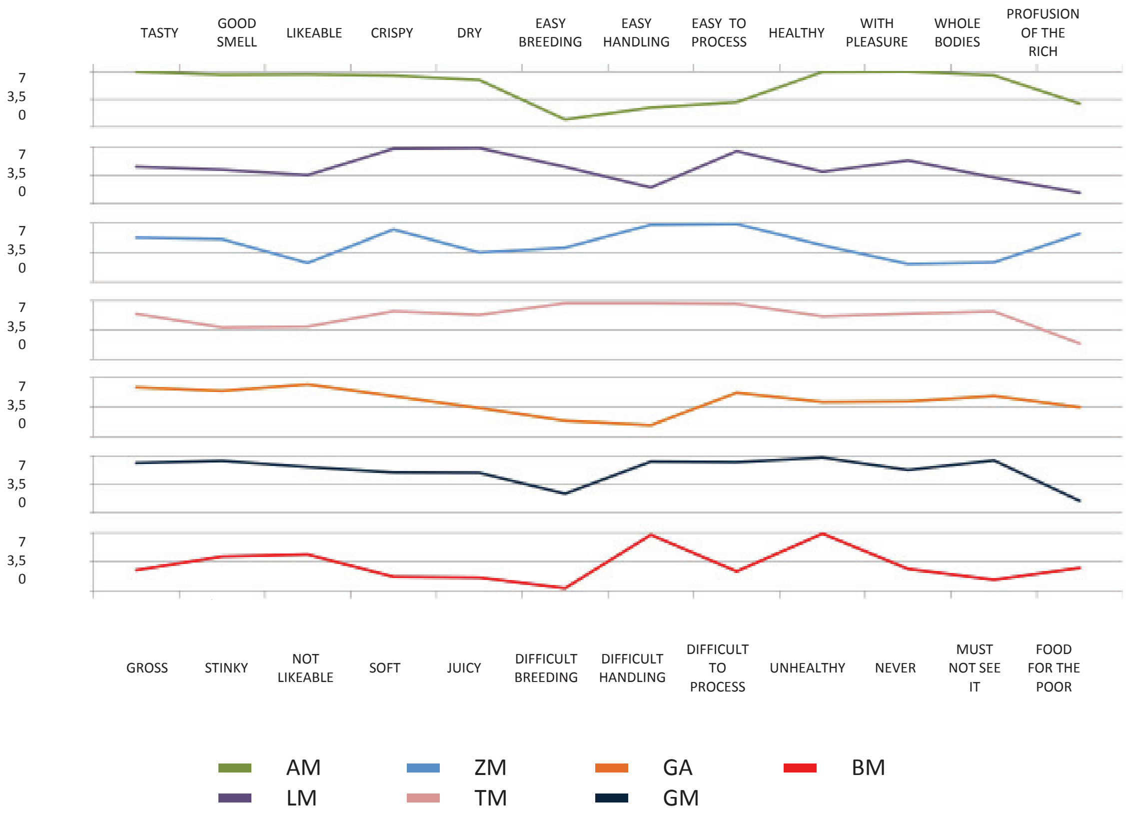
a) Acceptable species for entomophagous people

Based on the outputs of the first type of questionnaire, species that did not present insurmountable barrier for consumption were selected. Here it is necessary to mention one empirical experience of the authors, which, though not statistically measured yet, has influenced the answers of respondents, in our opinion. Although educational "bug banquets", according to some authors do not seem to be a very effective way to increase public interest in entomophagy (Looy and Wood, 2006), people who repeatedly took part in our lectures at different places of Czech Republic responded to insects and dishes from them significantly more positively, willing to try new offers and they considered insects completely natural food source.

From all insect species respondents chosed as acceptable: larvae of *Tenebrio molitor* (TM), *Galleria mellonella* caterpillars (GM), larvae of *Zophobas morio* (ZM), nymphs of *Locusta migratoria* (LM), larvae and pupae of beebrood *Apis mellifera* (AM), nymphs of *Gryllus assimillis* (GA) and pupae of *Bombyx mori* (BM) (Fig. 1), all in order from the most to the least acceptable. These species are very well accepted worldwide and especially BM and TM play an important role in research works regarding the future of human nutrition – on Earth and in space (Katayama *et al.*, 2008; Hu *et al.*, 2010; Oonincx *et al.*, 2010; Li *et al.*, 2012). Special place among these species belongs to beebrood (AM), because eating of it seems to be – on the contrary to other mentioned species – nothing unusual (particularly among beekeepers) in the Czech Republic. Regular consumption was confirmed by 5% of respondents, and 24% of respondents tasted it at least once in their lives. Cockroaches, on the other hand, completely failed in terms of acceptability, as only a thought of eating cockroaches caused aversion. For this reason, cockroaches were excluded from the subsequent analyses.

b) Selected species in terms of difficulty of breeding and culinary processing

As the toughest breedable species respondents selected BM, which also corresponds to reality. Caterpillars have to be fed fresh mulberry leaves, which is available only at certain times of the year, and breeding is also very challenging to manual work. There are also verified artifical diets, but they make the breeding considerably more expensive.



1: *Semantic differential*

On the contrary, breeding of TM seemed easy to respondents, clearly also because more than 30% of respondents had their own experience with that. This species appears to be essential for entomophagy, just for simplicity of breeding compared to other insect species evaluated, as well as other positive aspects associated with less impact on the environment compared with farm animals (Oonincx and DeBoer, 2012), which is a big advantage when introducing as food for humans. ZM and LM were marked as relatively easy to breed, but only 0.2% of respondents had their own experience with that. The questionnaire also revealed that in the kitchen, when preparing insect, respondents would have a problem neither with the larvae of TM and ZM, nor with LM and GM. On the contrary, they would not know what to do with BM and AM.

c) Sensory evaluation of selected insect species

Top rated were bee brood (AM) and LM. Surprisingly worst score was gained by the most often consumed species – TM and ZM, but also BM, where consumers mattered above all a very distinctive taste and consistency.

d) The inner attitude of respondents to selected types of insects

As "food for the poor" respondents evaluated mostly LM. This opinion originated probably due to the common idea of the natural habitat of thie species – that is, especially in the poor countries of Africa. Very similar classification was gained by GM and TM modes, the first as a species, which could be consumed by beekeepers and the second as – in the opinion of respondents – "enriches" flour routinely during commercial processing. Many people seem anthropo-entomophagy and "a poorman's subsistence" as a synonymum (Katayama *et al.*, 2008; Hu *et al.*, 2010), but there are also countries, where the consumption of insects promoted to elite dishes (DeFoliart, 1999; Nonaka, 2009). It depends always on the traditions and perspectives.

Respondents would be willing to consume bee brood as a whole, as well as TM and GM. On the other hand, large BM pupae, larvae of ZM and LM nymphs would be an issue. As far as these species are considered, respondents would rather welcome extracts of insect or crushed insects. All respondents would also like to taste or consume AM, while BM larvae and ZM pupae attracted only a very small part of the respondents.

Nutritional composition of selected insect species

Overall nutritional composition of the monitored species of insects or the contents of individual amino acids or fatty acids did not significantly differ from the range published in other similar works (Tab. I–III) (Bukkens, 1997; Ramos-Elorduy, 1997; Finke, 2005; Mitsuhashi, 2010; Schabel, 2010; Tomotake *et al.*, 2010) and the specific amount of each nutrient

I: *Basic nutritional values of selected insect species; one-way analysis of the variance-ratio test, including post-hoc Tukey's test;* ^{a,b,c,d,e} *– means marked with different letters within a given nutrient and a given insect species differ at P < 0.05*

Species	DM (%)	Moisture (%)	Protein (g/100g DM)	Fat (g/100g DM)	NFE (g/100g DM)	NDF (g/100g DM)	ADF (g/100g DM)	Ash (g/100g DM)	ME (kcal/100g DM)
BM	28.22^{b}	71.88^{d}	52.62^{b}	29.36^{b}	1.26^{a}	7.02^{a}	6.55^{d}	6.91^{c}	475.04^{b}
AM	17.33^{a}	82.76^{e}	54.38^{c}	31.24^{c}	1.99^{b}	5.66^{a}	5.16^{c}	4.25^{b}	498.63^{b}
LM	31.56^{c}	68.54^{c}	62.21^{e}	12.61^{a}	5.14^{c}	18.47^{c}	8.32^{e}	6.42^{c}	364.74^{a}
GM	39.67^{e}	60.43^{a}	38.41^{a}	56.65^{e}	2.16^{b}	17.14^{c}	4.43^{b}	2.65^{a}	665.46^{c}
GA	33.28^{c}	66.85^{c}	59.23^{d}	34.34^{c}	1.24^{a}	5.15^{a}	3.24^{a}	4.26^{b}	546.75^{b}
TM	37.45^{d}	62.62^{b}	50.86^{b}	36.10^{d}	6.41^{e}	14.16^{b}	4.26^{b}	3.84^{b}	536.36^{b}
ZM	40.61^{e}	59.47^{a}	54.25^{c}	40.26^{d}	2.55^{b}	13.61^{b}	3.61^{a}	3.65^{b}	582.28^{c}

II: *Aminoacids content of selected insect species; one-way analysis of the variance-ratio test, including post-hoc Tukey's test;* ^{a,b,c,d,e} *– means marked with different letters within a given nutrient and a given insect species differ at P < 0.05*

Amino Acids (g/100g DM)	ALA	ASP	ARG	CYS	GLY	GLU	HIS	ILE	LEU	LYS	MET	PHE	PRO	SER	THR	TRY	TYR	VAL
BM	4.82^{d}	6.47^{d}	3.93^{b}	0.93^{b}	3.62^{c}	6.58^{b}	1.44^{b}	2.12^{b}	2.84^{a}	3.92^{c}	1.94^{c}	2.11^{b}	2.06^{b}	2.16^{b}	1.33^{a}	0.51^{b}	1.53^{b}	2.41^{b}
AM	2.97^{b}	5.36^{c}	3.52^{b}	0.48^{a}	2.85^{b}	7.23^{b}	1.78^{b}	2.21^{b}	3.56^{a}	3.16^{b}	1.35^{b}	3.78^{d}	4.05^{d}	2.49^{b}	2.38^{b}	0.38^{b}	2.21^{c}	3.18^{c}
LM	3.25^{b}	4.14^{b}	2.91^{b}	1.94^{c}	3.02^{b}	6.24^{b}	1.66^{b}	2.48^{b}	5.02^{b}	2.92^{b}	2.16^{c}	5.61^{e}	3.24^{c}	3.87^{c}	2.94^{c}	1.84^{d}	1.66^{b}	3.93^{c}
GM	2.11^{a}	3.63^{b}	1.95^{a}	2.16^{c}	1.46^{a}	4.52^{a}	0.63^{a}	1.64^{a}	3.23^{a}	1.91^{a}	0.68^{a}	1.45^{b}	1.93^{b}	2.96^{b}	1.15^{a}	0.33^{b}	2.35^{c}	1.93^{b}
GA	4.02^{c}	3.02^{a}	8.64^{d}	0.74^{b}	2.41^{b}	3.64^{a}	1.32^{b}	2.12^{b}	4.96^{b}	7.91^{d}	0.63^{a}	0.72^{a}	1.26^{a}	0.61^{a}	3.55^{c}	0.95^{c}	5.44^{e}	4.62^{d}
TM	3.24^{b}	3.96^{b}	4.57^{c}	2.94^{d}	1.45^{a}	6.93^{b}	2.48^{c}	3.18^{c}	6.12^{c}	3.58^{c}	1.93^{c}	2.94^{c}	0.94^{a}	0.94^{a}	1.29^{a}	0.31^{b}	0.92^{a}	0.71^{a}
ZM	3.54^{c}	4.85^{c}	3.12^{b}	0.53^{a}	2.96^{b}	5.91^{b}	1.65^{b}	2.91^{c}	4.75^{b}	2.36^{a}	0.32^{a}	1.86^{b}	2.92^{c}	3.23^{b}	2.23^{b}	0.22^{a}	4.19^{d}	2.68^{b}

III: *Fatty acids content in selected insect species; one-way analysis of the variance-ratio test, including post-hoc Tukey's test;* ^{a,b,c,d,e} *– means marked with different letters within a given nutrient and given insect species differ at P < 0.05*

Fatty Acids (g/100g DM)	12:0	14:0	15:0	16:0	16:1	17:0	17:1	18:0	18:1	18:2	18:3	20:0	20:4	EPA	DHA
BM	1.22^{c}	1.16^{d}	0.91^{c}	2.12^{a}	0.18^{a}	0.86^{c}	0.23^{c}	1.46^{b}	2.23^{a}	3.17^{a}	9.13^{d}	0.94^{b}	0	0	0
AM	0.03^{a}	2.92^{e}	0	8.86^{b}	1.12^{c}	0	0	3.12^{c}	5.18^{c}	2.16^{a}	1.14^{c}	0.92^{b}	0	0	0
LM	0	0.19^{a}	0	1.93^{a}	2.13^{d}	0	0	1.88^{b}	2.13^{a}	3.55^{b}	0.64^{b}	0.01^{a}	0.01	0.01	0.02
GM	0	0.08^{a}	0	20.64^{d}	1.03^{b}	0	0.08^{b}	0.72^{a}	28.91^{e}	4.02^{b}	0.19^{a}	0.06^{a}	0	0	0
GA	0.81^{b}	1.90^{c}	0.12^{b}	20.55^{d}	0.98^{b}	0.42^{b}	0	0.42^{a}	3.25^{b}	4.92^{b}	0	0.82^{b}	0	0	0
TM	0	0.97^{b}	0	7.23^{b}	0.29^{a}	0	0	1.49^{b}	11.04^{d}	14.58^{d}	0	0.18^{a}	0	0	0
ZM	0	0.25^{a}	0.03^{a}	12.89^{c}	0.49^{a}	0.05^{a}	0.02^{a}	3.09^{c}	14.35^{d}	7.93^{c}	0	0.95^{b}	0	0	0

in many lines meet WHO requirements for human nutrition (WHO, 2007). Differences in nutrient composition may be due to management practices, different age of observed developmental stages and especially the diet composition (Fontaneto *et al.*, 2011).

In terms of further processing of live insects, dry matter content is an important factor. As we presume, that insect distribution and production of various types of food will be done in the dry state, the cost of drying would represent a relatively high proportion of total costs. From this perspective, optimal candidate seems to be ZM with 40.6% dry matter. On the other hand, processing of BM pupae, AM bee brood and GM caterpillars will be energy-consuming due to the low content of dry matter. The total content of fat and protein is an important decision factor in a need of a food with high protein content or with high content of fat and therefore energy. Nymphs of LM had the highest protein content while the total metabolizable energy was lowest of all evaluated species. Highest content of fat (56.6% / 100 grams of dry matter) was found in GM, while also this species had also the highest ME (665.46ME/100g of dry matter).

Nutritional and sensory profiles of selected species of insects

1. *Bombyx mori* pupae

Very nutritious insect, nutrient content meets the requirements for human nutrition. The disadvantage of this species while processed is lower dry matter content and availability in only a very limited part of the year while feeding natural diet (mulberry leaves). BM is generally a very good source of protein and fat. Semantic differential evaluated this species little bit negatively with ratio of negative:positive 8:4, considering the median value 3.5, which was worst of all investigated insect species. This may be due to the size of pupae, and also because it is quite unfamiliar commodity for Czech respondents. Consistency vas evaluated as unfavourable, being rather soft and juicy (respondents tend to prefer hard and crunchy). Furthermore, respondents see the difficulty of breeding and processing as a problem. The advantages seem to be easy handling with the pupae and high nutritional value.

2. *Apis mellifera* larvae and bee brood

Species with high nutritional value, but like BM available only in a certain part of the year and gaining of this product depends on the highly professional work of beekeepers. From all insect species AM had the highest level of Glutamic acid. Respondents see AM as very attractive for entomophagy, the ratio of negative and positive qualities was 4:8, which is the best ratio of all evaluated species. It is ranked as very healthy, most consumers would like to eat it again, or consume regularly and they would not mind seeing the larvae in the dish. Most respondents also stated, that AM smelled good to them.

3. *Locusta migratoria* nymphs

A good source of protein, the highest values of all evaluated species, low in fat. Thanks to the composition it is low caloric food source. LM has high content of NDF and ADF, and it is a good source of Linoleic acid (18:2) and Glutamic acid. Evaluated as a very good species with the ratio of 3:9 negative:positive. Manipulation was evaluated as little bit difficult. Due to their size, future consumers would appreciate if insect would not be seen in the food. LM was evaluated as food for the poor (in the Czech books of fiction this species is described as a diet of the eremites, and this dogma persists in the Czech Republic).

4. *Galleria mellonella* caterpillars

The highest content of fat of all evaluated insect species, and the lowest content of protein. With the highest amounts of ME it is rather the energy component of the diet. A good source of Oleic (18:1), and Palmitic (16:0) fatty acids (the highest value of evaluated species). This species was evaluated as the second best with the ratio of negative to the positive 2:10. Negative aspects were rather difficult breeding and considering this species as food for the poor.

5. *Gryllus assimillis* nymphs

Species with average nutritional composition in all the categories with the exception of Palmitic (16:0) fatty acid, of which it is quite a good source. It also contains high amount of Arginine (most of all evaluated species). From the perspective of entomophagous people GA is evaluated rather positively with the ratio of 4:8 (negative:positive). Respondents see mainly the breeding and processing as difficult, some of them also did not like the idea of biting into soft bodies. This species was evaluated moderately as food for the poor (similarly to LM).

6. *Tenebrio molitor* larvae

Species with average nutritional composition as well. Good source of Linoleic acid (18:2) (most of evaluated species). Respondents put this species on the first place of imaginary popularity ladder, with the ratio of negative to the positive 1:11. The only negative point was the evaluation as food for the poor, which is probably associated with the natural occurrence of these larvae, where many people noticed them – in the half-empty granaries. However, flavour and consistency were evaluated as exceptionally good. Also breeding and manipulation was considered easy. The species is seen as be more or less healthy, and the majority of respondents would be willing to consume foods with high visibility of larvae (which is an advantage in processing, as energy-consuming mechanical crushing or extraction of nutrients may be eliminated).

7. *Zophobas morio* larvae

This species has the lowest content of moisture, which could mean noticeable energy saving during further processing (especially drying). Levels of other nutrients are rather average, with a higher content of Oleic (18:1) fatty acids. Respondents evaluated this species rather positively with the ratio of 3:9, but quite an important attributes were negative – the appearance was described as unlovable, larvae should not rather be seen in food and many respondents would never be willing to taste this species. On the contrary, breeding and processing was rated positively (as easy), and well as the crunch while eating larvae. The species is regarded a profusion of the rich.

CONCLUSIONS

Find suitable species of insect for entomophagy in Czech Republic and analyse their nutritional values were the main parts of this research. Selected species were evaluated by consumers considering the sensory values, breeding, cooking/processing, and personal attitude of respondents. Analyses and questionnaires proved that, for Czech People the following species are suitable: *Tenebrio molitor* (TM) larvae, *Zophobas morio* (ZM) larvae, *Gryllus assimillis* (GA) nymphs, *Locusta migratoria* (LM) nymphs, *Galleria mellonella* (GM) larvae, *Bombyx mori* (BM) pupae and *Apis mellifera* (AM) bee brood. All species are bred in Czech Republic and there is no need to import them from abroad. Apart from BM and AM these insects are available all year round; TM is easily obtainable and easy to breed. BM, GM and LM can be evaluated as highly nutritive. Subjective evaluation by respondents lined these species according to popularity as follows (from the most to the least acceptable): 1. TM, 2. GM, 3. ZM, 4. LM, 5. AM, 6. GA, 7. BM. This work proved that the interest in entomophagy in Czech Republic grows and people do have general knowledge about usable species of insects.

SUMMARY

Aim of this work was to find suitable species for entomophagy in Czech Republic evaluate these species considering the nutritional value and gain the attitude of Czech people to the selected species. Insects used in this work were purchased from companies or institutions in the Czech Republic, frozen and later used for nutritional analyses. Insects were also used to prepare menus served on lectures and educational events, along with several forms of questionnaires. First type of questionnaires proved that the following species are suitable for entomophagy in the Czech Republic: *Tenebrio molitor* (TM) larvae, *Zophobas morio* (ZM) larvae, *Gryllus assimillis* (GA) nymphs, *Locusta migratoria* (LM) nymphs, *Galleria mellonella* (GM) larvae, *Bombyx mori* (BM) pupae and *Apis mellifera* (AM) bee brood. Cockroaches were completely excluded from further analyses, as they caused aversion. Nutritional analyses of selected species supported the idea of putting these species on the menu. Most species are rather protein than fatty food, with the exception of GM larvae, which have higher content of fat than of protein. GA is an important source of Palmitic acid (16:0), GM contains a lot of Palmitic (16:0) and Oleic acid (18:1), and TM is a good source of Linoleic acid (18:2). GA was found to have significantly high content of Arginine. To evaluate attitude to each species, semantic differential was used. This questionnaire was submitted to visitors of entomophagous events of all age categories, including pupils of all kinds of schools. Results of this survey enabled to compile a sort of "popularity ladder". TM placed first and GM second, followed by 3. ZM, 4. LM, 5. AM, 6. GA and 7. BM. The least problems with putting on the menu would cause the bee brood of AM, but this species placed fifth considering the difficulty of breeding. Species best accepted for entomophagy worldwide (in nutritional aspects) – pupae of BM – was evaluated as the least acceptable by Czech people. Overall, entomophagy is seen as acceptable with the possibility to include this food source in the diet of Czech people.

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