IS EDIBLE INSECT AS A NOVEL FOOD DIGESTIBLE?

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ABSTRACT

This work deals with the digestibility of a selected species of edible insect - mealworm (larvae) as novel food in dependency on its culinary treatment. The aim of this work was to find suitable thermic culinary treatment of mealworm larvae considering its optimum digestibility by human. The digestibility of materials from whole insect and extracted nitrogenous substances was determined using three different culinary treatments - without culinary treatment (freshly killed), dried insect and roasted insect. The digestibility was determined by gravimetric in vitro method using pepsin and pancreatin enzymes and their combination. The total nitrogen content of the insect samples was determined by the Kjeldahl method. The digestibility of the whole homogenized larvae using the combination of pepsin and pancreatin enzymes, thus simulating human digestion in-vitro, ranged from 81% for roasted specimens to 91.5% for culinary unprocessed insect. Similarly, the digestibility of nitrogenous substances of homogenized insect samples using this combination of enzymes ranged from 24.2% for roasted specimens to 80.2% for culinary unprocessed samples. The work showed the dependence of the digestibility of the mealworm larvae on the culinary treatment - the increasing heat load of the sample reduced the digestibility. Furthermore, it proved the effect of the digestive enzyme on the digestibility of the insect sample.

Keywords: digestibility; mealworm; culinary treatments; enzymes; nitrogenous substances

INTRODUCTION

Digestion is a physiological process in which nutrients contained in food are decomposed into a resorbable form. Nitrogenous substances, fats and carbohydrates have to be split up so that they can pass through the intestinal wall into the blood. The blood will transport them further to the necessary places in the organism where they are utilized (Mišurcová et al., 2010). Digestibility is most commonly determined as protein digestibility. To a large extent, this digestibility is influenced by the culinary treatment. Culinary treatment, especially cooking and frying, improves sensory quality of food, and induces formation of flavours, attractive colours and textures. Cooking also improves hygienic quality by inactivating some pathogenic microorganisms, improves digestibility and increases the bioavailability of certain nutrients in the gastrointestinal tract (Bognár, 1998).

At present, many studies (Megido et al., 2018; Grabowsky and Klein, 2017; Klunder et al., 2012; Vandeweyer et al., 2017) deal with the hygiene and food safety conditions applicable in the European food industry for edible insect, but only a few studies deal with the influence of culinary treatment on the edible insect nutritional value. This creates an information gap for everyday consumers, chefs, cookbooks authors, etc., who have minimal access to information about a safe and healthy way to cook edible insect (Megido et al., 2018). Due to the increasing demand for commodities of animal origin, focusing on protein sources and their digestibility, consumer pressure is also increasing to fill this information gap (Mlček et al., 2014; Tan, Berg and Siëger, 2016; Adámková, 2017). In addition, the availability of this information may reduce fears in the part of the European public about the consumption of edible insect (Yen, 2009).

During the heat treatment of food, proteins are denatured, amino acids modified or destroyed and Maillard reaction occurs. In the heat treatment, proteins may also interact with other proteins or with oxidizing agents, sugars, polyphenols, tannins or solvents (Finot, 1983). Denaturation at higher temperatures results to better enzymatically digestible proteins due to cleavage of developed polypeptide chains or inactivation of antinutritional compounds (Finot, 1983; Opstvedt et al., 2003). On the other hand, the digestibility of proteins may be reduced by reacting with each other and by reacting with amino acids which cannot subsequently be hydrolysed by digestive enzymes (Opstvedt et al., 2003).

The question of the use of edible insect as part of feed in livestock and pets (dogs, cats, etc.) has been dealt with by several studies (Bosch et al., 2014; McCusker et al., 2016; Mlček et al., 2014). Digestibility is most commonly determined as protein digestibility. To a large extent, this digestibility is influenced by the culinary treatment. Culinary treatment, especially cooking and frying, improves sensory quality of food, and induces formation of flavours, attractive colours and textures. Cooking also improves hygienic quality by inactivating some pathogenic microorganisms, improves digestibility and increases the bioavailability of certain nutrients in the gastrointestinal tract (Bognár, 1998).

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In spite of these data, the knowledge about digestibility of edible insect in humans is minimal. The reason is physiological differences and differences in the composition of digestive juices, therefore the digestibility of this commodity may be different in man and animal (Bussink et al., 2007). Due to the inclusion of edible insect in the "novel food" category in European countries, the solution to this issue becomes important when a complex view of edible insect is needed, concerning not only nutritional or sensory properties, but also the digestibility.

For this reason, this study focused on digestibility of edible insect, which assumes that digestibility is different for different culinary treatments of insect. The aim was to find a suitable heat culinary treatment of the mealworm in terms of its optimum digestibility by man. Because of the inclusion of edible insect in the novel food category, comparison is also required with other commodities of animal origin. For this reason, this study focused on digestibility of edible insect, which assumes that digestibility is different for different culinary treatments of insect.

**Scientific hypothesis**

Scientific hypothesis is: the digestibility of edible insect materials is dependent on culinary treatments. The aim was to find a suitable heat culinary treatment of the mealworm in terms of its optimum digestibility by man. Because of the inclusion of edible insect in the novel food category, comparison is also required with other commodities of animal origin.

**MATERIAL AND METHODOLOGY**

**Material**

For the analysis, samples of mealworm larvae (Tenebrio molitor) were used for analysis. Samples were purchased at a pet store. Prior to analysis, insect samples were treated as follows: mealworm larvae in the last and penultimate stages were taken from the breed and left to starve for 24 hours. Subsequently, the insect was killed with boiling water (100 °C) and dried with a warm air stream at a temperature of 75 °C ± 5 °C for 30 s. Samples of killed and wiped larvae were divided into three experimental groups with the following treatment procedures:

1. no treatment – freshly killed insect with no further culinary treatment
2. dried insect – killing, subsequent drying for 2 minutes at 120 °C and then drying for 5 – 7 minutes at 70 – 80 °C
3. roasted insect – killing, subsequent roasting for 4 minutes at 160 °C.

After treatment, all samples were homogenized and stored in cooling box at 4 – 7 °C until analysis.

**Dry matter digestibility determination**

Determination of digestibility was performed by gravimetric in vitro method using a Daisy incubator (ANKOM Technology, USA). For digestion, pepsin EC 3.4.23.1 from porcine gastric mucosa (activity: 0.7 FIP-U.g⁻¹) and pancreatin from pancreas (protease activity: 350 FIP-U.g⁻¹, lipase activity: 6000 FIP-U.g⁻¹, amylase activity: 7500 FIP-U.g⁻¹) were used. Both enzymes were supplied by Merck (Darmstadt, Germany).

Enzymatic hydrolysis involved hydrolysis by pepsin (0.5 g enzyme per g sample), pancreatin (0.5 g enzyme per 1 g of sample) and combined hydrolysis with pepsin and subsequently with pancreatin. In case of hydrolysis by pepsin, digestibility was measured after 30 minutes. For pancreatin hydrolysis, digestibility was determined after 6 hours. In the case of combined hydrolysis, the pepsin enzyme was left to function for 30 minutes, followed by the pancreatin enzyme treatment for 6 hours. Samples were evaluated 3 times. The determination was carried out according to the modified methodology (Mišurcová et al., 2010; Mišurcová, 2008).

For determination of digestibility, 0.5 g of sample was weighed into F57 filter bags with a porosity of 25 μm (ANKOM Technology, USA). The bags were sealed, placed in incubation flasks containing 1.7 liters of the appropriate solution (in the case of pepsin 0.1 M HCl, in the case of pancreatin pH 7.45 phosphate buffer), conditioned to 40 °C and added to adequate amount of the corresponding enzyme to meet the above requirement of 0.5 g of enzyme per 1 g of sample. Together with the samples, a sealed control bag without a sample was placed in the incubation bottle. This was followed by hydrolysis for the time intervals mentioned above. After the hydrolysis was complete, the bags were washed with distilled water, dried for 24 hours at 103 °C and weighted.

In the case of combined hydrolysis, the samples were first hydrolysed with pepsin, and hydrolysis with pancreatin was initiated immediately after completion of the pepsin hydrolysis and washing of the bags in distilled water (Mišurcová et al., 2010; Mišurcová, 2008).

**Determination of nitrogenous substances digestibility**

To determine the digestibility of nitrogenous substances, the nitrogen content of the non-hydrolysed samples and the nitrogen content of the samples enzymatically hydrolysed with pepsin, pancreatin and combined – pepsin and then pancreatin – had to be evaluated. Enzymatic hydrolysis was carried out as described above. The total nitrogen content of both hydrolysed and non-hydrolysed insect samples was determined by the Kjeldahl method using an automatic distillation unit Pro Nitro A (JP Selecta S.A., Spain). The results were expressed as a percentage in the form of the coefficient of digestibility of the nitrogenous compounds.

The coefficient of digestibility of nitrogenous compounds (KS) can be calculated according to the equation below (1). To calculate the digestibility coefficient, the nitrogen content of the non-hydrolysed samples (NLN) from equation (2) and the nitrogen content of the hydrolysed samples (NLH) from equation (3) (Mišurcová, 2008) must be determined. Samples were measured 2 times.
The digestibility was determined, on the basis of the determination of the digestibility decreased. The lowest digestibility values were reached by the combination of pepsin and pancreatin enzymes. In this case, digestibility was over 80% for all culinary treatments (no processing, drying and roasting). This combined hydrolysis is most similar to human digestion from the hydrolysis types used in this work.

Due to the non-compliance with the homogeneity condition for some sample sets, the Kruskal-Wallis test and the multiple comparison of the p-values were selected for the comparison of the groups. The results of comparison of the groups are shown in Table 2. In this table a statistically significant difference between roasted and untreated samples by pepsin hydrolysis can be seen. A statistically significant difference (p <0.01) between unprocessed and roasted samples can also be found in pancreatin hydrolysis. In hydrolysis by the combination of these enzymes, a statistically significant difference was found between the dried and untreated samples. No other statistically significant difference was found in this study, although some differences can already be traced from the chart.

For each sample gained by hydrolysis the content of crude protein was analysed, Table 3. This value was used to calculate the digestibility of the nitrogenous substances. From the measured values of nitrogenous substances for individual samples, their digestibility coefficient (%), content of nitrogenous substances in non-hydrolysed samples (%), content of nitrogenous substances in hydrolysed samples (%), determined by Pro Nitro in non-hydrolysed samples (mg), determined by Pro Nitro in hydrolysed samples (mg), sample weight (mg), and conversion factor (f = 6.25).

### Table 1 The digestibility of samples [g.100g⁻¹].

|                | no processing | dried insect | roasted insect |
|----------------|---------------|--------------|----------------|
| **M ± SD**     | M ± SD        | M ± SD       | M ± SD         |
| Pepsin         | 86.7 ± 0.8    | 50.4 ± 9.2   | 47.2 ± 9.8     |
| Pancreatin     | 89.8 ± 0.7    | 80.8 ± 1.4   | 75.3 ± 4.7     |
| Pe-Pa          | 91.5 ± 0.6    | 80.3 ± 0.9   | 81.0 ± 0.5     |

Note: Pe-Pa – combined hydrolysis using pepsin and pancreatin.
samples with culinary treatment can be seen. It is believed that the decline in digestibility is due to the formation of enzymatically unprocessable complexes due to the increasing heat effect of heat culinary treatment.

**Discussion**

Several parameters can affect digestibility, e.g. chitin content, phytate content, interaction of individual nutrients, oxidative changes, etc. The results are simulated in vitro, so they can be different from real digestive processes (Sváčina, 2010). Poelaert et al. (2016) determined the digestibility of unprocessed mealworm dry matter by in-vitro method (IVDM) 76.2%. This result is lower than in this work. Similarly, this was also the case with thermal effects on commodities, where Poelaert et al. (2016) declared an 18% lower digestibility than that measured in this work. However, the trend is similar in both researches. In accordance with this work, Poelaert et al. (2016) noticed reduced protein digestibility when using a heat processing of up to 13% when samples were autoclaved.

When comparing with mealworm, Poelaert et al. (2016) declared up to 23% lower digestibility of the house cricket dry matter depending on the heat treatment. However, protein digestibility (IVCPD) is comparable in both species. Poelaert et al. (2016) also reports a comparison with commodities of plant origin (beans, lentils, peas, soybean), where the digestibility is mostly lower in raw state and the significantly increases with raising temperature - the lentils had an increase in digestibility by up to 28%. Generally, however, the digestibility of dry matter in these commodities of plant origin is up to tens of % lower than determined by Poelaert et al. (2016) in their work for a mealworm or than the values in this study.

In terms of nutritional values, however, the more important is the digestibility of crude proteins determined in vitro (IVCPD). Besides Poelaert et al. (2016) also Marono et al. (2015), Caparros Megido (2017), and Panini et al., (2017) dealt with it. Panini et al., (2017) for his research on “alternative protein source for Pacific white shrimp” reported a 45.9% dry matter digestibility and 76.1% protein digestibility for “mealworm meal”. Marono et al. (2015) declared the protein digestibility of “insect meals” from different suppliers ranging from 65.5% to 66.7%. These values are comparable to the values (59.5% – 72.5%) reported by Poelaert et al. (2016) and values measured in this work but, are lower than the values (85.0% – 91.5%) reported by Megido et al. (2018). Although the difference in digestibility between Poelaert et al. (2016) and Megido et al. (2018) was 13% for a crude insect sample, Poelaert et al. (2016) declared it as the highest, and Megido et al. (2018) as the lowest. From the results reported by Megido et al. (2018), therefore, the trend is the increasing protein digestibility with raising the temperature. On the contrary, Poelaert et al. (2016) show the opposite trend - heat treatment reduces protein digestibility. This trend can also be seen for the results in this work. However, the specific values are not completely comparable, due to different experimental methodology (e.g. time and temperature of hydrolysis, selected enzyme

### Table 2

Multiple comparison of the p-values for different culinary treatments and hydrolysates with pepsin, pancreatin and their combination.

| Dependent value | Pepsin | Pancreatin | Pepsin + Pancreatin |
|-----------------|--------|------------|---------------------|
| No treatment    |        |            |                     |
| Drying          | 0.072337 | 0.349993  | 0.018119            |
| Roasting        | 0.042684 | 0.005106  | 0.149581            |

### Table 3

Nitrogenous substances content in samples [g.100g⁻¹].

|                | No hydrolysis | Pepsin | Pancreatin | Pe-Pa |
|----------------|---------------|--------|------------|-------|
|                | M              | S      | M          | S     |
| M              | 204.2          | 1.7    | 739.4      | 24.8  |
| SD             | 188.0          | 2.1    |            |       |
| M              | 58.8           | 4.4    | 668.8      | 0.8   |
| S              | 184.2          | 2.5    |            |       |
| M              | 54.0           | 3.2    | 618.9      | 8.6   |
| S              | 171.9          | 1.4    |            |       |
| M              | 40.5           | 1.2    | 560.3      | 11.0  |
| S              | 149.2          | 0.9    |            |       |

Note: PePa - combined hydrolysis using pepsin and pancreatin.
Table 4 Digestibility of nitrogenous substances after culinary treatment and hydrolysis with the selected enzyme.

| Sample                  | Nonhydrolyzed sample [g.100g⁻¹] | Hydrolyzed sample [g.100g⁻¹] | Digestibility [%] |
|-------------------------|----------------------------------|------------------------------|-------------------|
| Pepsin                  | 204.2                            | 58.8                         | 71.2              |
| Pancreatin              | 204.2                            | 54.0                         | 73.5              |
| Pepsin and pancreatin   | 204.2                            | 40.5                         | 80.2              |
| Drying                  |                                  |                              |                   |
| Pepsin                  | 488.0                            | 184.2                        | 62.3              |
| Pancreatin              | 488.0                            | 171.9                        | 64.8              |
| Pepsin and pancreatin   | 488.0                            | 149.2                        | 69.4              |
| Roasting                |                                  |                              |                   |
| Pepsin                  | 739.4                            | 668.8                        | 9.5               |
| Pancreatin              | 739.4                            | 618.9                        | 16.3              |
| Pepsin and pancreatin   | 739.4                            | 560.3                        | 24.2              |

When comparing digestibility with samples of animal origin, Megido et al. (2018) pointed out the match of their results with other commodities - beef (89%), pork (90%), turkey meat (78%) and salmon (85%) (Bodwell, Satterlee and Hackler, 1980). They declared the differences from other studies were due to the different “raw materials” and the use of various “different batches of mealworms” with different fat or antinutritional factors content. At higher temperatures, digestibility is reduced as a result of the formation of difficult-to-digest protein complexes with oxidized fats. In addition, digestibility can be reduced by, for example, reacting with mineral substances and reacting minerals with one another. Reagents, such as phosphorus and calcium, form an insoluble complex (phytates) that reduces the digestibility of proteins and makes them inaccessible (El Hassan et al., 2008).

Similar to other commodities, the heat can not only positively affect the properties, but can also lead to a reduction in nutritional value, e.g. by oxidation of amino acids or by changing or losing essential amino acids, or even creating substances that are undesirable from the point of view of health (toxic, carcinogenic or mutagenic effects substances). Highly dangerous substances can arise from proteins of animal origin (i.e. insect), and therefore all excessively browned to blackened portions of the food should be removed. Insect, in our case, mealworm is a specific biological material. Despite being regarded a farm animal after being included into novel foods by EFSA, it has a different anatomy and physiology of the body than ordinary livestock (mammals). Therefore, it should be borne in mind that, from the nutritional point of view, this commodity contains, in addition to fat and crude protein, a considerable amount of chitin (Adámková et al., 2017). However, the European consumer does not have enough chitinase to digest it.

CONCLUSION

The digestibility of edible insect, on which this work was focused, is dependent on subsequent culinary treatments. In terms of the digestibility of the dry matter, the highly in-vitro digestible sample of the mealworm is thermally untreated and the most difficult for digesting is sample after roasting. However, for the safety reasons, it is not possible to recommend the consumption of unprocessed mealworm meal by humans. However, insect can be used both as dried and uncooked (freshly killed) as feed for farm animals. Even in the case of nitrogen digestibility analysis, the highest digestibility value was detected for thermally unprocessed insect. From a safety point of view, the heat treatment by drying is more suitable, which reduces the digestibility of nitrogenous substances, but not so much as in the case of roasting. The practical use of this work lies in the contribution of knowledge that could enable the fortification of food by the addition of commodity from edible insect ideally roasted. However, due to the possible formation of dangerous roasting complexes (Maillard reaction), further analyses are needed in this area.

REFERENCES

Adámková, A. 2017. Nutriční rozhod a optimalizace chovu vybraných druhů jedlého hmyzu v podmínkách ČR s ohledem na zdraví člověka (Nutritional Analysis and Optimization of Breeding of Selected Insect Species in Conditions of the Czech Republic with Regard to Human Health) : dissertation theses. Prague, Czech Republic : Czech Agriculture university in Prague, Faculty of Agrobiology, Food and Natural Resources Department of Agricultural Product Quality. (In Czech)

Adámková, A., Kouřímská, L., Borkovečová, M., Kulma, M., Mlček, J. 2016. Nutritional values of edible Coleoptera (Tenebrio molitor, Zophobas morio and Alphitobius diaperinus) reared in the Czech Republic. Potravinářstvo, vol. 10, no. 1, p. 663-671. [https://doi.org/10.5219/609]

Bodwell, C. E., Satterlee, L. D., Hackler, L. R. 1980. Protein digestibility of the same protein preparations by human and rat assays and by in vitro enzymic digestion methods. The American journal of clinical nutrition, vol. 33, no. 3, p. 677-686. [https://doi.org/10.1093/ajcn/33.3.677]

Bogňár, A. 1998. Comparative study of frying to other cooking techniques influence on the nutritive value. Grasas y Aceites, vol. 49, no. 3-4, p. 250-260. [https://doi.org/10.3989/gya.1998.v49.3-4.746]

Bosch, G., Zhang, S., Oonincx, D. G. A. B., Hendriks, W. H. 2014. Protein quality of insects as potential ingredients for dog and cat foods. Journal of Nutritional Science, vol. 3. [https://doi.org/10.1017/jns.2014.23]

Bussink, A. P., Speijer, D., Aerts, J. M., Boot, R. G. 2007. Evolution of mammalian chitinase (-like) members of family
18 glycosyl hydrolases. *Genetics*, vol. 177, no. 2, p. 959-970. https://doi.org/10.1534/genetics.107.075846

Caparrós Megido, R., Desmedt, S., Blecker, C., Béra, F., Haubreug, É., Alabi, T., Francis, F. 2017. Microbiological load of edible insects found in Belgium. *Insects*, vol. 8, no. 1, p. 12. https://doi.org/10.3390/insects8010012

De Marco, M., Martínez, S., Hernandez, F., Madrid, J., Gai, F., Rotolo, L., Belforti, M., Bergero, D., Katz, H., Dabbou, S., Kovitvadhii, A., Zoccarato, I., Gasco, L., Schiavone, A. 2015. Nutritional value of two insect larval meals (*Tenebrio molitor* and *Hermetia illucess*) for broiler chickens: apparent nutrient digestibility, apparent ileal amino acid digestibility and apparent metabolizable energy. *Animal Feed Science and Technology*, vol. 209, p. 211-218. https://doi.org/10.1016/j.anifeedsci.2015.08.006

El Hassan, N. M., Hamed, S. Y., Hassan, A. B., Eltayeb, M. M., Babiker, E. E. 2008. Nutritional evaluation and physiochemical properties of boiled and fried tree locust. *Pakistan Journal of Nutrition*, vol. 7, no. 2, p. 325-329. https://doi.org/10.3923/pjn.2008.325.329

Finot, P. A. 1983. Influence of processing on the nutritional value of proteins. *Plant foods for human nutrition*, vol. 32, no. 3-4, p. 439-453. https://doi.org/10.1007/BF01091200

Grabowski, N. T., Klein, G. 2017. Microbiology of processed edible insect products – Results of a preliminary survey. *International Journal of Food Microbiology*, vol. 243, p. 103-107. https://doi.org/10.1016/j.ijfoodmicro.2016.11.005

Guikema, J. W. 2004. Scanning hall probe microscopy of magnetic vortices in very underdoped yttrium-barium-cooperoxide : dissertation theses. Serra Mall, Stanford, USA : Stanford University, 177 p.

Klunder, H. C., Wolkers-Cooper, J., Korpela, J. M., Nout, M. J. R. 2012. Microbiological aspects of processing and storage of edible insects. *Food Control*, vol. 26, no. 2, p. 628-631. https://doi.org/10.1016/j.foodcont.2012.02.013

Marono, S., Piccolo, G., Loponte, R., Di Meo, C., Attia, Y. A., Nizza, A., Bovera, F. 2015. In vitro crude protein digestibility of *Tenebrio molitor* and *Hermetia illucess* insect meals and its correlation with chemical composition traits. *Italian journal of animal science*, vol. 14, no. 3, p. 338-343. https://doi.org/10.4081/ijas.2015.3889

McCusker, S., Buff, P. R., Yu, Z., Fasceiti, A. J. 2014. Amino acid content of selected plant, algae and insect species: a search for alternative protein sources for use in pet foods. *Journal of nutritional science*, vol. 3, no. 3, p. e39. https://doi.org/10.1017/jns.2014.33

Megido, R. C., Poelaert, C., Errens, M., Liotta, M., Blecker, C., Danthine, S., Tyteca, E., Haubreug, É., Alabi, T., Bindelle, J., Francis, F. 2018. Effect of household cooking techniques on the microbiological load and the nutritional quality of mealworms (*Tenebrio molitor L.* 1758). *Food Research International*, vol. 106, p. 503-508. https://doi.org/10.1016/j.foodres.2018.01.002

Mišurcová, L., Kráčmar, S., Klejds, B., Vacek, J. 2010. Nitrogen content, dietary fiber, and digestibility in algal food products. *Czech Journal of Food Sciences*, vol. 28, no. 1, p. 27-35. https://doi.org/10.17221/111/2009-cjfs

Mlček, J., Rap, O., Borkovcová, M., Bednarova, M. 2014. A comprehensive look at the possibilities of edible insects as food in Europe—a review. *Polish Journal of Food and Nutrition Sciences*, vol. 64, no. 3, p. 147-157. https://doi.org/10.2478/v10222-012-0099-8

Opstevedt, J., Nygård, E., Samuelsen, T. A., Venturini, G., Luzzana, U., Mundheim, H. 2003. Effect on protein digestibility of different processing conditions in the production of fish meal and fish feed. *Journal of the Science Food and Agriculture*, vol. 83, no. 8, p. 775-782. https://doi.org/10.1002/jsfa.1396

Pamini, R. L., Freitas, L. E. L., Guimarães, A. M., Rios, C., da Silva, M. F. O., Vieira, F. N., Fracalossi, D. M., Samuels R. I., Prudêncio, E. S., Silva, C. P., Amboni, R. D. M. C. 2017. Potential use of mealworms as an alternative protein source for Pacific white shrimp: digestibility and performance. *Aquaculture*, vol. 473, p. 115-120. https://doi.org/10.1016/j.aquaculture.2017.02.008

Poelaert, C., Beckers, Y., Desprez, X., Portetelle, D., Francis, F., Bindelle, J. 2016. In vitro evaluation of fermentation characteristics of two types of insects as potential novel protein feeds for pigs. *Journal of Animal Science*, vol. 94, no. 3, p. 198-201. https://doi.org/10.2527/jas.2015-9533

Svačina, Š. 2010. Metabolism and nutrition disorders (Poruchy metabolismu a výživy). 1st ed. Prague, Czech Republic : Galén, 505 p. ISBN: 978-7262. (In Czech)

Tan, H. S. G., van den Berg, E., Steiger, M. 2016. The influence of product preparation, familiarity and individual traits on the consumer acceptance of insects as food. *Food quality and preference*, vol. 52, p. 222-231. https://doi.org/10.1016/j.foodqual.2016.05.003

Vandeweyer, D., Lenaerts, S., Callens, A., Van Campenhout, L. 2017. Effect of blanching followed by refrigerated storage or industrial microwave drying on the microbial load of yellow mealworm larvae (*Tenebrio molitor*). *Food Control*, vol. 71, p. 311-314. https://doi.org/10.1016/j.foodcont.2016.07.011

Yen, A. L. 2009. Edible insects: Traditional knowledge or western phobia? *Journal of the Entomological Research Society*, vol. 39, no. 5, p. 289-298. https://doi.org/10.1111/j.1748-5967.2009.00239.x

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