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Comparison of functional properties of edible insects and protein preparations thereof

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ABSTRACT

This study investigated the functional properties of three species of edible insects: *Gryllodes sigillatus*, *Schistocerca gregaria*, and *Tenebrio molitor*. The water and oil holding capacity, solubility, and foaming and emulsion properties were evaluated. The protein solubility showed minimum values at pH 5. The highest water and oil holding capacity was noticeable for the *T. molitor* protein preparation (3.95 g/g) and for the *G. sigilltus* protein preparation (3.33 g/g), respectively. The *G. sigillatus* protein preparation also showed the highest foaming capacity, foam stability, and emulsion activity (99.0%, 92.0%, and 72.62%, respectively), while the protein preparation from *S. gregaria* exhibited the highest emulsion stability (51.31%). This study has shown that whole insects and protein preparations thereof can be suitable for development of new food formulations.

1. Introduction

In the last decade, the interest of entomophagy has been continuously growing. Currently, insects are consumed by two billion people worldwide and even insect foods have recently become available in the US and Europe. More than 2100 insect species have been documented in literature as edible (Jongema, 2017). Moreover, insects are still promoted as a good source of protein and the production of edible insects in developing countries is supported by various institutions such as the Food and Agriculture Organization of the United Nations. However, the use of insects in food production requires further investigations at different levels, for example to search for opportunities to use them in various forms. This may be necessary since Western consumers may be reluctant to accept insects as a protein source (Shelomi, 2015). In many countries, whole insects are often consumed but they can also be processed to pastes and powders; furthermore, insect proteins, fats, and chitin can be isolated before use in food products as well. This could be a useful way for increasing acceptability among wary consumers. Edible insects can also be processed into a more palatable form by grinding or milling. It is an easy way to obtain high-protein insect flour with other valuable components such as vitamins or minerals (Yi et al., 2013).

Several studies have shown that edible insects are a good source of protein (Ramos-Elorduy, Moreno, & Camacho, 2012; Rumpold & Schlüter, 2013; Zielińska, Baraniak, Karaś, Rybczyńska, & Jakubczyk, 2015) but there are only few data about the functional properties of insect protein. These properties could be helpful to clarify the use of insect powder or protein extracts in different food products, for example bread, pasta, and dairy products.

Currently, many commercial food products are fortified in order to increase their nutritional value. For example, ham is enriched with protein derived from legumes and fruit juices are enriched with vitamins. Edible insects are a great material for food fortification for several reasons. First of all, they are rich in protein of high biological value with a good amino acid profile and a high level of digestibility. Moreover, insects are a good source of a variety of micronutrients such as minerals: copper, iron, magnesium, manganese, phosphorous, selenium, and zinc and vitamins: riboflavin, pantothenic acid, biotin, and folic acid (Ramos-Elorduy et al., 2012; Rumpold & Schlüter, 2013). Their lipid profile is desirable for humans. They are a source of unsaturated fatty acids, for example omega-3 (Zielińska et al., 2015). Given their nutritional value, insects can be a good product for food supplementation and entomophagy does not have to be associated with the consumption of whole insects any more.

In this study, three species of insects (*Tenebrio molitor*, *Schistocerca gregaria*, *Gryllodes sigillatus*) were selected, which are well known and easy to breed in Europe; each of them belongs to a different order or family and is bred widely in Europe. These species have also been reported to have the biggest potential to be used as food and feed in the EU (EFSA, 2015). Moreover, the nutritional value of these insects was

Abbreviations: *G. sigillatus*, *Gryllodes sigillatus*; *S. gregaria*, *Schistocerca gregaria*; *T. molitor*, *Tenebrio molitor*; TNBS, picrylsulfonic acid; OHC, oil holding capacity; WHC, water holding capacity; FC, foaming capacity; FS, foam stability; EA, emulsion activity; ES, emulsion stability

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studied. The most important information for determination of the functional properties is the protein content, and the studied species contain 52.35, 76.0, and 70.0% of protein, respectively (Zielińska et al., 2015). The physicochemical properties of proteins, protein size, and flexibility play an important role in determining their functional properties, for example small molecular weight proteins give very good emulsion-forming abilities because of rapid diffusion to the interface. Proteins are commonly used to improve the functional properties of food compositions. In fact, the functional properties of proteins are dependent on pH.

The aim of this study was to determine the functional properties of flours and protein preparations obtained from edible insects. In this study, the solubility, water and oil holding capacity, and foaming and emulsifying properties were determined.

2. Materials and methods

2.1. Raw materials

The mealworms *Tenebrio molitor* (Linnaeus, Coleoptera: Tenebrionidae) (larvae), locusts *Schistocerca gregaria* (Forskal, Orthoptera: Acrididae) (adult), and crickets *Gryllodes sigillatus* (Fabricius, Orthoptera: Gryllidae) (adult) were obtained from a commercial supplier from Poland. All individuals of these species were fasted for approximately 48 h to clear their gastrointestinal tract of any residual food. For each species tested, approximately 0.5 kg of material was frozen and lyophilized. The insects were ground in a laboratory grinder.

2.2. Method for obtaining the protein preparation

Proteins were isolated according to the Girón-Calle, Alaiz, and Vioque (2010) method with slight modification. Briefly, insect flour was stirred for 1 h with 0.2% NaOH at a ratio of 1:10 (w/v), pH 11, at room temperature. After centrifugation at 8,000*g*, precipitation of proteins was carried out at the isoelectric point pH 4.5 and room temperature. Precipitated proteins were centrifuged at 4 °C for 20 min at 8000 g and washed with distilled water. Afterwards, the protein preparations were lyophilized and kept at −18 °C until further analysis.

2.3. Solubility

The protein solubility was determined according to the method of Castellani, Martinet, David-Briand, Guérin-Dubiard, and Anton (2003) with a slight modification. The sample was dispersed in distilled water and the pH of the mixture was adjusted to 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11 using 1 or 6 mol/L HCl and 1 or 6 mol/L NaOH. The volume of the mixture was adjusted to obtain the final concentration of protein (10 mg/ml). Total protein content in the sample was determined after solubilization of the sample in 0.5 mol/L NaOH. The mixture was stirred for 90 min and centrifuged at 8,000*g* for 15 min. The protein content in the supernatant was determined using the Bradford method (1976). Protein solubility was calculated from the formula:

$$\text{Solubility (\%)} = (P_s/P_t) \times 100$$

where: P_s – protein content in the supernatant, P_t – total protein content in the sample.

2.4. Water holding capacity

Water holding capacity (WHC) was determined according to the method of Diniz and Martin (1997) with a slight modification. The sample (0.5 g) was dispersed in 20 ml of distilled water and stirred with a shaker at 540 rpm for 30 min. Afterwards, the dispersion was centrifuged at 8,000*g* for 15 min. The precipitate was weighed and the difference in the weight was calculated. The results were presented as gram of water absorbed per gram of the sample.

2.5. Oil holding capacity

Oil holding capacity (OHC) was determined according to the method of Haque and Mozaffar (1992) with a slight modification. The sample (0.5 g) was added to 10 ml of vegetable oil and mixed for 30 s in a vortex mixer. Afterwards, the dispersion was centrifuged at 8,000*g* for 15 min. The precipitate was weighed and the difference in the weight was calculated. The results were presented as gram of oil absorbed per gram of the sample.

2.6. Foaming properties

Foaming capacity (FC) and foam stability (FS) were determined according to the method of Guo et al. (2015). Twenty milliliter of a 1% sample was homogenized in a high shear homogenizer mixer (pol-eko H500, Poland) at a speed of 16,000 rpm for 2 min. The whipped sample was immediately transferred into a cylinder. The total volume was read at time zero and 30 min after homogenization. The foaming capacity and foam stability were calculated from the formula:

$$\text{Foaming capacity (FC) (\%)} = [(V_0 - V)/V] \times 100$$

$$\text{Foam stability (FS) (\%)} = (V_{30}/V_0) \times 100$$

Where: V – volume before whipping (ml), V_0 – volume after whipping (ml), V_{30} – volume after standing (ml).

2.7. Emulsifying properties

Emulsifying properties were determined according to the method of Wu, Wang, Ma, and Ren (2009). The sample was dispersed in distilled water (1% w/v) and 15 ml of the dispersion were homogenized (pol-eko H500, Poland) with 15 ml of vegetable oil at a speed of 20,000 rpm for 1 min. Afterwards, the samples were centrifuged at 3000 g for 5 min and the volume of the individual layers were read. Emulsion stability was evaluated by heating the emulsion for 30 min at 80 °C. Then, the samples were centrifuged at 3000 g for 5 min. Emulsion activity and emulsion stability were calculated from the formula:

$$\text{Emulsion activity (EA) (\%)} = (V_e/V) \times 100$$

$$\text{Emulsion stability (ES) (\%)} = (V_{30}/V_e) \times 100$$

Where: V – total volume of tube contents, V_e – volume of the emulsified layer, V_{30} – volume of the emulsified layer after heating.

2.8. The sensory evaluation

The panel for sensory analysis was composed of 75 members aged from 21 to 30 years (58 women, 17 men). The characteristics of the flours and protein preparations, such as color, consistency, smell, and overall acceptability were evaluated on a scale of 1–5 (1–bad, 5–very good).

2.9. Statistical analysis

All experiments were run in triplicate and the results were presented as means ± standard deviation. Statistical analysis was performed using the STATISTICA v. 10.0 for one-way analysis of variance (ANOVA) and the differences of the means between the samples were determined using the Tukey test. P-values below 0.05 were considered significant.