**Sponge cake enriched with cricket powder and mesquite flour as a protein source**

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The high nutritional value of edible insects attracted the attention of researchers and the food industry for their potential use in foods with enhanced nutritional characteristics. In this study cricket (Acheta domesticus) powder and mesquite flour was added to wheat flour and sugar to obtain sponge cake with enhanced nutritional value. The present study assessed the nutritional profile, sensory, and color quality of cake enriched with cricket powder and mesquite flour to determine their nutritional relevance and suitability for improving population nutritional health. The incorporation of cricket powder and mesquite flour in the cake resulted in high protein, high fiber, and low carbohydrate content, and darker color of bakery products. Besides the increased nutrients content of cake enriched with 20% cricket powder, consumer acceptability and physical quality were comparable to control products. The results clearly showed the applicability of sponge cakes enriched with 20% cricket powder and mesquite flour for improving the population's nutritional health and well-being.

**Keywords**: sponge cake, mesquite, cricket powder, protein, color.

**Introduction**

The high nutritional value of edible insects has been attracting the attention of researchers and the food industry for their potential use in the formulation of foods with enhanced nutritional characteristics. Indeed, insects are very rich in proteins and essential amino acids (Belluco et al., 2013).

Тhe European Food Safety Authority (EFSA) recently proposed a list of insect species with the greatest potential to be used as food and feed in the EU, including the following: *Musca domestica, Hermetia illucens, Tenebrio molitor, Zophobas atratus, Alphitobius diaperinus, Galleria mellonella, Achroia grisella, Bombyx mori, Acheta domesticus, Gryllodes sigillatus, Locusta migratoria migratorioides*, and *Schistocerca americana* (EFSA Scientific Committee, 2015).

Cricket powder obtained from these insects is characterized by high protein content (about 60–70%), a lack of carbohydrates, and high iron and calcium content (Ayieko et al., 2016). An FAO report explicitly recommends the use of insects as a source of easily digestible protein, especially in the face of rapid population growth in the world and the growing difficulty of providing sufficient food (van Huis, 2013). Some European countries have regulated the production of insect-based foods before, but from 1st January 2018, insects, as well as their parts, were officially released for sale as a so-called “novel food”. These products are subject to pre-market authorization before being made available for sale. Changes to the law in the EU regarding the admission of insects production for consumption have created new opportunities to use this source of protein (C/2017/8878).

Very recently, de Oliveira, da Silva Lucas, Lopes Cadaval, and Sallas Mellado (2017) proposed the use of cinereous cockroach (*Nauphoeta cinerea*) flour to enrich the protein content of wheat bread.

The cake is a bakery product obtained by baking a mixture of flour, sugar, eggs, and fats. Today, the cake represents one of the most important and consumed food in the daily diet worldwide.

Mesquite powder (*Prosopis alba*) is the product obtained by grinding the whole pods. Besides fiber, it also has proteins, lipids and provides calcium and iron, among other minerals. The level of protein is variable (7-11 g/100g) (Prokopiuk et al., 2000; Bigne et al., 2016). Several authors (Roccia et al., 2010; Mohammed et al., 2012; Boukid et al., 2019) found that the replacement of wheat flour with different amounts of leguminous powder or protein isolates obtained from them (chickpea flour, soy flour, mesquite flour) affected the rheological properties of dough due to network weakening and consequently, the quality of the final product such as volume, internal structure, and texture of the bread (Mohammed et al., 2014). Bigne et al., (2016, 2018) reported that the high level of fiber in mesquite flour led to changes in the textural properties of dough, as a consequence of an inferior development of the gluten network.

With the growing awareness of consumers towards innovative and wholesome bakery products, the production of special goods, gluten-free and a whole range of tasty and innovative variables of sponge cake, have increased, hence edible insects can constitute a novel source of innovative ingredients to be used in cake making.

The aim of this study was the evaluation of cricket (*Acheta domesticus*) powder to obtain sponge cakes with enhanced nutritional value. Experimental cakes were obtained from batters produced using different blends of wheat flour, mesquite powder, and cricket powder. Technological, nutritional, and sensory traits of the obtained batters and sponge cakes were finally assessed.

**Material and methods**

**Material**

Wheat flour (type 500) was obtained from a commercial mill (GoodMills, Bulgaria). Sugar and eggs were purchased from a local market. The cricket powder, produced from Sens Foods (London, UK), contained 70.00% protein; 20.00% fat, of which saturates – 5.20%; 0.50% carbohydrates and 9.50% fiber, 5.67 mg iron. The mesquite powder with origin Peru, importer Burel Organics LTD (Sofia, Bulgaria), contained 2.3% fat, 78.40% carbohydrates, and 10.80% protein.

**Methods**

**Preparation of sponge cakes**

The control cake was prepared, following a traditional technology and formulation (Angelov et al., 1974). The batter formulation of the control cake was as follows (based on batter weight): egg yolk 13.35%, egg white 29.88%, refined granulated sugar 25.90%, and wheat flour 30.88%. In particular, a double mixing procedure was applied by partitioning the whipping of whites and egg yolks. Mesquite powder was added to cake batter in 30% as natural sugar substitutes.

Sugar is the main ingredient of the control cake formulation (about 26% of the batter ingredients). The recipe compositions of the control sample and the investigated cakes containing sugar substitutes mix are presented in Table 1.

The stages of technology were kept because of their easy fulfillment and the considerably small duration of the technological cycle. The sponge cakes with 10% and 20% cricket powder were processed at a constant regime of baking concurrent with that of the control sample, which according to the technological instruction was baked for 30 min at 180 °С (Figure 1).

Each sponge cake batter of 65 g was poured out into metallic forms and baked in an electric oven at 180°C for 30 min. The sponge cakes were stored at standard conditions (at a temperature of 18°C and 75 % relative humidity). The humidity and the temperature were kept constant by means of a desiccator supplied with a psychrometer and put in a thermostat with an accuracy of ±0.5°C.

**Table 1. Sponge cake batters formulations**

|  |  |  |  |
| --- | --- | --- | --- |
| **Ingredients** | **Amount based on batter weight:** | | |
| **control sample** | **with 10% cricket powder** | **with 20% cricket powder** |
| Yolk of egg, [%] | 13.35 | 13.35 | 13.35 |
| White of egg, [%] | 29.87 | 29.88 | 29.88 |
| Granulated sugar, [%] | 25.90 | 17.93 | 17.93 |
| Wheat flour, [%] | 30.88 | 27.89 | 24.90 |
| Mesquite flour, [%] | - | 7.97 | 7.97 |
| Cricket powder, [%] | - | 2.98 | 5.97 |

**Proximate composition analysis**

Protein content was determined by the Kjeldahl method, according to EN ISO 20483 (*N* = 6.25), and total fat content was determined according to AACC 30–25.01. The moisture content was analyzed according to AACC 44-19.01. The proximate carbohydrate content was estimated by subtracting the total fat, protein, and moisture content from 100%. AOAC fiber method.

**Color measurements**

The color of the crumb cake was measured using a colorimeter. Differences in color were recorded in the CIE L\*a\*b\* scale in terms of lightness (*L\**) and color (*a\** – redness, *b\** – yellowness). Color measurement was repeated 15 times for each sample. Additionally, the total color difference (Δ*E*) was calculated using the following formula:

, where Δ*L*\*, Δ*a*\*, and Δ*b*\* are differences in the *L*\*, *a*\*, *b*\* values between the reference sample and the test sample respectively.

**Sensory evaluation**

The descriptive test for quantitative sensory profiling was used to establish the sensory characteristics (shape, color, cell size and uniformity, odor, sweetness, aftertaste, crumb tenderness) of the sponge cakes, 6 h after baking, following the ISO 8586:2014 and ISO 13299:2016 methods. The sponge cake samples were ready 1 h before the evaluation. Samples of different cakes were kept in coded plates covered with aluminum foil. Twelve trained panelists were selected to guarantee the evaluation accuracy. The intensity of each sensory characteristic was recorded on a ten-point linear scale after 1 h orientation sessions of the panelists, where they specified terminology and anchor points on the scale. The coded samples were shown simultaneously and evaluated in random order among the panelists.

**Statistical analysis**

All experiments were performed in triplicate. The data were analyzed and presented as mean values±standard deviation. Statistical analysis was conducted using the Statgraphics Centurion XVI Version 16.2.04 software (Statpoint Technologies Inc., USA). The analysis of variance technique, incl. Lavene’s test (ANOVA) and Multiple Range Test were used to determining significant differences at a 95 % confidence level (p < 0.05).

**Results and discussion**

**Nutritional value**

Crickets and cricket powder are good sources of nutritionally valuable compounds – proteins, lipids, and, especially, polyunsaturated fatty acids and minerals, such as calcium, iron, or zinc (Ayieko et al., 2016). The substitution of wheat flour with cricket powder changed the nutritional value of the products, due to the high quality and digestibility of protein and the content of essential amino acids (Zielińska et al., 2015). The protein content in cake enriched with cricket powder significantly increased (starting from the 5% addition level) with the increasing percentage of cricket powder in the product (Table 2). Global trends in food design favor increased protein content in low sugar products (Anderson et al., 2012). Adding cricket powder to the flour mixture increased the protein content from 9.09 g/100 g to 15.01 g/100 g in the case of 10% enrichment, to 18.22 g/100 g at 20% enrichment. Carbohydrate content was decreased from 58.21 g/100 g to 24.50 g/100 g in the case of 10% cricket powder, 21.01 g/100 g in the case of 20% cricket powder. The energy value was decreased by 121.94 kcal, in the case of 20% cricket powder enrichment. The fat content shows a smaller difference, while the fiber content increased in proportion to the enrichment (increased from 2.21 g/100 g to 10.34 g/100 g in the case of 20% cricket powder). Similar results were observed in the case of the protein content of wheat flour bread with house cricket and cinereous cockroach powder enrichment (De Olivieira et al., 2017; Osimani et al., 2018), rice flour cakes with Bombay locust powder enrichment (Indriani et al., 2020).

**Table 2. Chemical composition and energy value of sponge cakes (100 g product)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Basic chemical composition and energy value** | **Type of sponge cakes** | | |
| **control sample** | **with 10% cricket powder** | **with 20% cricket powder** |
| Total moisture, [%] | 23.44 ±0.04b | 26.40±0.01c | 27.33±0.01c |
| Protein, (g/100 g) | 9.09±0.10b | 15.01±0.01c | 18.22±0.01d |
| Fat, (g/100 g) | 6.89±0.03d | 5.45±0.02c | 4.01±0.01b |
| Carbohydrateа, (g/100 g) | 58.21±0.31d | 24.50±0.00bc | 21.01±0.01b |
| Total dietary fibre, (g/100 g) | 2.21±0.28b | 8.50±0.01c | 10.34±0.01d |
| Energy value,  [kJ/100 g]  [kcal/100 g] | 1403.60  335.63 | 937.14  224.09 | 893.65  213.69 |

а “Carbohydrate” any carbohydrate which is metabolized by the human body with the exception of dietary fiber according to Regulation (EU) № 1169/2011.

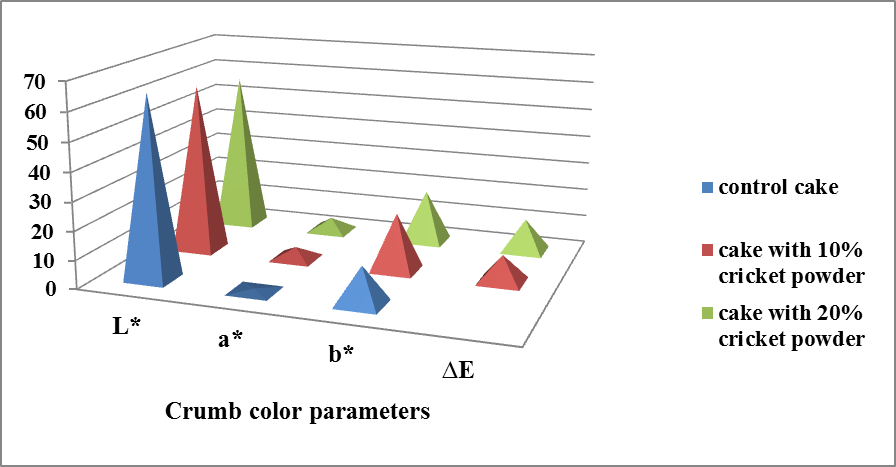
b-d The values in a line with identical letters do not differ statistically significantly (p < 0.05).

The European Union’s Regulation No. 1924/2006 on nutrition and health claims made on foods states: ‘a claim that a food is a source of protein, and any claim likely to have the same meaning for the consumer, may only be made where at least 12% of the energy value of the food is provided by protein’; A claim that a food is high in protein, and any claim likely to have the same meaning for the consumer, may only be made where at least 20 % of the energy value of the food is provided by protein (EC Regulation 1924/2006). According to this Regulation, the products with cricket powder and mesquite powder enrichment can be labeled as HIGH PROTEIN, since 26.79% (sponge cake with 10% cricket powder and mesquite) and 34.11% (sponge cake with 20% cricket powder and mesquite) of their energy value is provided by protein.

The results indicated that there was a significant increase in the total dietary fiber content in sponge cakes incorporated with natural protein sources – cricket and mesquite powder. The highest amount of total dietary fiber had cake with 10% cricket powder (8.50%) and cake with 20% cricket powder (10.34%), while it was 2.21% for control cake. It is important to note that sponge cakes with natural protein sources could be tagged as foods and could support the claim “with high content of dietary fiber”, according to the provisions of FAO/WHO guidelines (Codex Alimentarius Commission & FAO, 2009) because they exceed the 6 g of TDF per 100 g of product.

**Crumb color of sponge cakes**

The appearance and color of the product are the key parameters that determine desirability. Consumers usually perceive darker cakes as healthier and containing more fiber or whole grains. Sciammaro, Ferrero, & Puppo, 2016 indicated that the color of crumbs depends on the conditions of the technological process – caramelization and Maillard reactions may take place simultaneously, and both reactions depend on temperature, the content of reducing sugars, and amino groups. Ronda et al. (2005) proved that changes in the sugar content can also contribute to changes in the color of the products. The use of CP to enrich the cakes with protein caused significant changes in the color of the products (Figure 1). Maillard browning occurs when amino acids and reducing sugars are heated, for example during baking. Increased protein content may contribute to the easier formation of Maillard reaction products (melanoidins), which are responsible for reducing the lightness of muffins. The lightness (L\*) of cakes is significantly reduced as the percentage of CP increases. In contrast, cakes with 20% CP were lighter than 10% CP and control cake. As the color change cannot be analyzed just in terms of lightness, it should be noted that saturation of green and blue increased in all samples. The total color difference (ΔE > 7) value indicates a significant effect of CP addition on the color of cakes. Instrumental color measurement of color change was in accordance with the results of visual evaluation by consumers.



\* ΔE was not determined for the control (0%) crickets powder inclusion

**Figure 1. Color parameters (*L*\*, *a*\*, *b*\* and Δ*E*) of control cake (0% cricket and mesquite powder inclusion) and cake enriched with 10%, and 20% cricket powder**

The darker color of the cakes enriched with cricket powder is very probably owing to the incorporation of cricket powder in cake, which increased the availability of free amino acids due to the added protein. This facilitates the fusion of the reducing sugar with the nucleophilic amino acid, via the carbonyl group of the reducing sugar to enhance the Maillard reaction (Manley, 2011). Additionally, the brown color of the cricket powder contributed to the substantial dark color at high levels of inclusion. Nonetheless, this did not affect the overall acceptability at 10% and 20% cricket powder inclusion (Figure 2). More importantly, we realized that the color parameters of a product alone do not explain a high consumer score. Consumer preference is also associated with the nutrients content of the products (Osimani et al., 2018; González et al., 2019).

**Sensory analysis**

High nutritional value and health-promoting properties must be accompanied by sensory attractiveness (Sun-Waterhouse and Wadhwa, 2013) to create a viable product. Taste, smell and appearance are some of the most important factors that influence a consumer’s decision to purchase. Data presented in Figure 2 shows that the control cake had the highest appearance rating, compared to all the enriched cakes.

**Figure 2. Sensory evaluation**

The sensory analysis demonstrates that the structure is fine-porous in all kinds of investigated sponge cakes. The control cake and the cakes with cricket powder have an approximately similar form. The crumb pores of cakes with cricket powder in the investigated three kinds of cakes are with thicker walls, small and equal in size. The odor of the cakes with cricket powder is perceived as more pleasant than the control cake-sample one. The color of the cakes with cricket powder is perceived well by the testers. The intensity of the sweetness for all investigated sponge cakes is close. Cakes with 10% and 20% cricket powder were characterized by attractive brown color, small size, and proper distribution of pores, and were distinguished for their desirable sensory quality.

It was observed that the higher crumb tenderness scores for control increased the overall liking values. The crumb pore cells of the cake with 20% cricket powder had thicker walls, and they were larger and equal in size. The cells of the sponge cake-control were smaller and almost uniformly distributed in the crumb, with thinner walls. The cake-control had a crust and crumb with a more pronounced light-yellow color due to the presence of the color components in the yolks of the eggs (carotenoids). The color of the crust and crumb of the cakes with 10%, and 20% cricket powder are light-brown with brown nuance. The odor of all cakes is perceived by the sensory panelists as pleasant. The intensity of the sweetness for all investigated sponge cakes is close.

**Conclusion**

It was found that the addition of cricket powder increased the content of protein and ash and decreased the carbohydrate content of the product. Despite the changes in the proportions of protein and carbohydrate, no effect on energy value was noted. Enrichment with cricket powder caused a reduction in the lightness of cakes. Reductions in red and yellow color saturation were also observed. Nevertheless, the results of consumer acceptance tests indicate that cakes with a small amount of added cricket powder were considered as attractive as conventional products, and, as a source of protein, could also be a solution to functional food and undernourishment.

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**References**

AACC International 2000. Approved methods of the American Association of Cereal Chemists (10th ed.). St. Paul: AACC International.

Anderson, G.H., Foreyt, J., Sigman-Grant, M. & Allison, D.B. 2012. The use of low-calorie sweeteners by adults: Impact on weight management. J. Nutr., 142(6), 1163s– 1169s. <https://doi.org/10.3945/jn.111.149617>

Angelov L., Bekirov B., Genadieva, M. & Atanasov S. 1974. ON 146 200-72. In Handbook of branch standards, rates of consumption and technological instructions in confectionaryture, I, pp. 176-183.

Ayieko, M.A., Ogola, H.J. & Ayieko, I. A. 2016. Introducing rearing crickets (gryllids) at household levels: Adoption, processing and nutritional values. J. Ins. Food Feed, 2(3), 203–211. https://doi.org/10.3920/JIFF2015.0080

Belluco, S., Losasso, C., Maggioletti, M., Alonzi, C. C., Paoletti, M. G., & Ricci, A. 2013. Edible insects in a food safety and nutritional perspective: A critical review. Comprehensive Reviews in Food Science and Food Safety, 12, 296–313.

Bigne F., Puppo M. C. & Ferrero C. 2016. Rheological and microstructure characterization of composite dough with wheat and mesquite (Prosopis spp.) flours, Int. J. Food Prop., 19(2), pp. 243–256.

Bigne, F., Puppo, M. C. & Ferrero, C. 2018. Mesquite (*Prosopis alba*) flour as a novel ingredient for obtaining a “panettone-like” bread. Applicability of part-baking technology, LWT Food Sci. Technol., 89, pp. 666–673.

Boukid, F., Vittadini, E., Lusuardi, F., Ganino ,T., Carini, E., Morreale, F. & Pellegrini, N. 2019. Does cell wall integrity in legumes flours modulate physiochemical quality and in vitro starch hydrolysis of gluten-free bread, Journal of Functional Foods, 59, pp. 110-118.

C/2017/8878. Commission Implementing Regulation (EU) 2017/2470 of 20 December 2017 establishing the Union list of novel foods in accordance with Regulation (EU) 2015/2283 of the European Parliament and of the Council on novel foods. OJ L 351/72, 30.12.2017.

De Oliveira, L. M., da Silva Lucas, A. J., Lopes Cadaval, C., & Sallas Mellado, M. 2017. Bread enriched with flour from cinereous cockroach (Nauphoeta cinerea). Innovative Food Science & Emerging Technologies, 44, 30–35.

EC Regulation No 1924/2006 of the European Parliament and the of the Council on Nutrition and Health Claims Made on Foods; 1924/2006/EC. 2006. Available online: <http://data.europa.eu/eli/reg/2006/1924/oj> (accessed on 10 June 2021).

EFSA Scientific Committee (2015). Scientific Opinion on a risk profile related to production and consumption of insects as food and feed. EFSA Journal, 13(10), 4257. http://dx.doi.org/10.2903/j.efsa.2015.4257 (60 pp.).

EN ISO 20483:2013. Cereals and pulses – Determination of the nitrogen content and calculation of the crude protein content – Kjeldahl method. Warszawa: PKN.

González, C.M., Garzón, R., & Rosell, C.M. 2018. Insects as ingredients for bakery goods. A comparison study of H. illucens, A. domestica and T. molitor flours. Innovative Food Science & Emerging Technologies. <http://dx.doi.org/10.1016/j.ifset.2018.03.021>.

Indriani, S., Bin Ab Karim, M.S., Nalinanon, S. & Karnjanapratum, S. 2020. Quality characteristics of protein-enriched brown rice flour and cake a\_ected by Bombay locust (*Patanga succincta* L.) powder fortification. LWT, 119, 108876.

Manley, D. 2011. *Technology of biscuits, crackers and cookies* (4th ed.). Sawston, UK: Woodhead Publication. González, C., Garzón, R., & Rosell, C. (2019). Insects as ingredients for bakery goods. A comparison study of *H. illucens*, *A. domestica* and *T. molitor* flours. *Innovative Food Science & Emerging Technologies*, *51*, 205–210.

Michalska, A., Amigo-Benavent, M., Zieliński, H. & del Castillo, M. D. 2008. Effect of bread making on formation of Maillard reaction products contributing to the overall antioxidant activity of rye bread. J. Cereal Sci., 48(1), 123–132. <https://doi.org/10.1016/j.jcs.2007.08.012>

Mildner-Szkudlarz, S., Siger, A., Szwengiel, A. & Bajerska, J. 2015. Natural compounds from grape by-products enhance nutritive value and reduce formation of CML in model muffins. Food Chem., 172(1), 78–85. https://doi.org/10.1016/j.foodchem.2014.09.036

Mohammed, I., Ahmed, A.R. & Senge, B. 2012. Dough rheology and bread quality of wheat-chickpea flour blends, Industrial Crops and Products, 36(1), pp. 196-202.

Mohammed, I., Ahmed, A.R. & Senge, B. 2014. Effects of chickpea flour on wheat pasting properties and bread making quality, Journal of Food Science and Technology, 51(9), pp. 1902-1910.

Osimani, A., Milanović, V., Cardinali, F., Roncolini, A., Garofalo, C., Clementi, F. & Aquilanti, L. 2018. Bread enriched with cricket powder (*Acheta domesticus*): A technological, microbiological and nutritional evaluation. Innovative Food Science & Emerging Technologies, 48, 150–163. <https://doi.org/10.1016/j.ifset.2018.06.007>

Prokopiuk, D., Cruz, G., Grados, N., Garro, O., & Chiralt, A. 2000. Estudio comparativo entre frutos de prosopis alba y prosopis pallida, Multequina, 9, pp. 35-45.

Roccia, P., Ribotta, P.D., Ferrero, C., Perez, G.T., Leon, A.E. 2010. Enzymes action on wheatesoy dough properties and bread quality, Food and Bioprocess Technology, 5(4), pp. 1255-1264.

Sciammaro, L., Ferrero, C. & Puppo, M.C. 2016. Chemical and nutritional properties of different fractions of Prosopis alba pods and seeds. Journal of Food Measurement and Characterization, 10 (1), pp. 103-112.

van Huis, A. 2013. Potential of insects as food and feed in assuring food security. Ann. Rev. Entomol., 58, 563–583. https://doi.org/10.1146/annurev-ento-120811-153704

Zielińska, E., Baraniak, B., Karaś, M., Rybczyńska, K. & Jakubczyk, A. 2015. Selected species of edible insects as a source of nutrient composition. Food Res. Int., 77(3), 460–466.