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EFFECT OF CRICKET POWDER ADDITION ON TECHNOLOGICAL PROPERTIES AND QUALITY OF SAUSAGES

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ABSTRACT

Edible insects are increasingly explored as alternative protein sources for the feed and food industry due to their potential for sustainable, high-quality protein production. The use of a powdered form of an insect in a ready-to-eat food can increase the willingness to consume insects. This study evaluates the chemical composition, colour, texture and sensory properties of sausages with the addition of cricket powder (3%, 6%, and 12% of cricket powder). The addition of cricket powder significantly increased the protein content of the sausages ($p < 0.05$). As the addition of cricket powder increased, the sausages became darker both on the surface and on the cut ($p < 0.05$). The textural properties were not affected by the addition of cricket powder ($p > 0.05$). For sensory descriptors, sausages without cricket powder scored the highest, and the scores decreased as the amount of cricket powder increased ($p < 0.05$) except odour where no significant differences were found ($p < 0.05$). The results showed that cricket powder can be used at lower levels in meat products without affecting sensory quality.

Keywords: edible insect, meat products, colour, texture, sensory analysis

INTRODUCTION

Edible insects are currently much discussed in the context of alternative protein sources for the feed and food industry **(Pavelková *et al.*, 2022).** There are many studies on the chemical composition and nutritional value of edible insects **(Oliveira *et al.*, 2024; Patel *et al.*, 2019; Rumpold and Schlüter, 2013)**. The various species of edible insects generally contain a high level of complete and relatively easily digestible protein in the dry matter (13–77%), similar in amino acid composition to chicken or fish protein. However, the amount and quality of protein depends on many factors such as the species of insect and the quality of its fattening **(Raheem *et al.*, 2019; Syahrulawal *et al.*, 2023)**. In addition to protein, edible insects also contain fats (2–50% of dry matter) with appropriate fatty acid composition especially in the larval stage **(DeFoliart, 1992)**, minerals such as copper, selenium, iron, zinc, calcium, magnesium and manganese, vitamins mainly from the B group **(Rumpold and Schlüter, 2013; Baiano, 2020)**, bioactive peptides such as polyphenols, antioxidant enzymes, antimicrobial peptides/proteins, etc. **(Nongonierma and FitzGerald, 2017)** and finally fibres in the form of chitin, which forms the exoskeleton of edible insects **(van Huis *et al.*, 2013)**. In the context of chitin, it should be added that people who are allergic to crustaceans, crabs, lobster shells, etc. may also be allergic to chitin from insects. People with an allergy to crustaceans should therefore be careful and avoid eating insects **(Syahrulawal *et al.*, 2023)**. Despite the positive aspects of using insects as food mentioned above, edible insects do not attract much interest from most Western consumers. This food neophobia is based on a mistrust of the health safety of edible insects in relation to unclean environments, diseases or parasites **(Acosta-Estrada *et al.*, 2021)**. The challenge for producers and processors of insects for food will therefore be to provide consumers with relevant arguments about the safety of insects to reduce neophobia as much as possible. By following good hygiene and production practices, the risks can be eliminated **(Loony *et al.*, 2014)**. The form of previous processing can also influence the perception of insects. Consumers are more open to consuming insects in processed powdered form **(Ayieko *et al.*, 2021)**. The use of a powdered form of an insect in a ready-to-eat food, in which the consumer does not associate any visual similarity with the insect, may increase the willingness to consume insects repeatedly **(Patel *et al.*, 2019)**. A few studies investigated the use of these features in common food products such as bakery and meat products, or in different meat analogues or other food substitutes **(Borges *et al.*, 2022)**. The aim of these studies was to investigate the effect of addition an insect raw material on the technological and sensory properties that are important for good quality of final products **(Kim *et al.*, 2017)**. These properties are also important for consumer when making an initial food choice **(Acosta-Estrada *et al.*, 2021)**. The aim of this study was to evaluate the chemical composition, colour, texture and sensory properties of sausages with the addition of cricket powder.

MATERIAL AND METHODS

Sausages production

Cricket powder was added to the experimental variants in accordance with the recipe in **Table 1**. The cricket powder (*Acheta domestica*) was purchased from a distributor of edible insect products Grig s.r.o. (Brno, Czech Republic). The cricket powder contains 2.92 ± 2.20 $g.100g^{-1}$ of water, 66.50 ± 0.74 $g.100g^{-1}$ of protein, and 19.23 ± 1.25 $g.100g^{-1}$ of fat. This protein composition corresponds to other findings in dry matter of cricket powders. Fat content was higher than in other studies **(Stone *et al.*, 2019; Rumpold and Schlüter, 2013; Pavelková *et al.*, 2022)**. The cricket powder was stored in the refrigerator (Liebherr, Germany) at 4°C until processing. Lean and fatty pork was purchased from a local abattoir (Jatka Ivančice s.r.o., Czech Republic), delivered to the meat pilot plant (CZ22067) of the Department of Food Technology, Mendel University in Brno and stored 1day at a temperature below 3 °C. Before production, it was portioned and cleaned of remaining skins and tendons. Spice mixture (pepper, cumin, garlic, juniper, bay leaf, phosphate E451, antioxidant E316, monosodium glutamate E621), salt mixture (with 0.5% sodium nitrite), and pork casings were purchased from specialized company MASO-PROFIT s.r.o. (Brno, Czech Republic). The sausages were produced in 2 batches of 4 kg each. Lean pork (contains less than 5% of fat from adipose tissue), and fatty pork (contains 50% of fat from adipose tissue) were mechanically minced into 12 mm pieces (TMP 23-98, Braher, Spain) and mixed (RC-100, MAINCA, Spain) with salt mixture, spice mixture and water in form of ice. Cricket powder was added at the end of mixing according to the specific variant. This mixture was minced again into 8 mm pieces (TMP 23-98, Braher, Spain). Control variant without cricket powder were marked as C, variant with 3% cricket powder content were marked as CP3, variant with 6% of cricket powder CP6 and variant with 12% cricket powder CP12. Meat batter was filled (HTS 95, HTS Fleischereimaschinen, Austria) into pork casings (30/32 mm diameter). Then they were hung by hand on a smoke cart. Products were heat-treated (70°C, 10 min in core) and smoked (Bastramat B 850 FR, BASTRA GmbH, Germany). The heat treatment was followed by rapid cooling. When the products reached 5°C in the core, they were transferred to the cold store where they remained for 1 day at 4°C. The products were then taken for all subsequent analysis.

Table 1 Recipe of sausages (kg.100 kg^{-1})

Lean pork	41.10
Fatty pork	50.20
Water	5.94
Salt mixture	1.76
Spice mixture	1.00

Chemical analysis of sausage and cricked powder

For formulating sausage recipes, the basic composition of cricket powder was analysed (water content (g.100g^{-1}) (**AOAC, 2005a**), fat content (g.100g^{-1}) (**AOAC, 1996**), protein content (g.100g^{-1}) (**AOAC, 2002**). From each group of sausages samples was taken 250 g and homogenised. It was determined water content (g.100g^{-1}) (**AOAC, 2005a**), fat content (g.100g^{-1}) (**AOAC, 1996**), protein content (g.100g^{-1}) (**AOAC, 2002**), and salt content (g.100g^{-1}) (**AOAC, 2005b**). All analyses were conducted three times.

Colour measurement

The *L**, *a** and *b** colour parameters in the CIELAB colour space were used to determine colour differences using the CM 3500d spectrophotometer (Konica Minolta, Japan). The samples were measured (D 65, 6500 °K) on the surface of the sausage and in the cut in SCE (Specular Component Excluded) mode and 8 mm slit in triplicate (3 measurements for each product in 2 batches).

Texture properties

The texture properties of the sausages were measured with a TIRATEST 27 025 texturometer 114 (TIRA Maschinenbau GmbH, Germany). Samples were tempered to 20 °C before measuring. The analysis was performed using a MORS knife with a crosshead speed of 50 mm.min^{-1} and penetration to 10 mm.

Sensory analysis

Sensory analysis was performed according to ISO 8589 standards in the corresponding sensory laboratory. Before evaluation, the samples were taken out of the refrigerator and tempered to laboratory temperature (20°C), sausages were cut into 5 mm slices. Each sample was labelled with a randomly generated four-digit number and all were submitted together in random order to the assessors for evaluation. Samples were evaluated by a panel of 10 trained assessors in accordance with ISO 8586-1. An unstructured line scale of 100 mm was used for all descriptors, with anchor points at the two ends of the line scale. The use of mostly hedonic attributes was chosen, including acceptability of appearance, acceptability of colour on the surface and on the cut, acceptability of hardness, sandiness, smell, taste, juiciness, astringency and overall impression (0 points for an unsatisfactory sample, 100 points for an excellent sample) **(Caparros Megido *et al.*, 2016; Pavelková *et al.*, 2022; Cavalheiro *et al.*, 2023)**. The only intensity attribute was chosen because of the nutty flavour that is associated with the addition of insects (0 points no nutty flavour, 100 points strong nutty flavour).

Statistical analysis

Data normality was tested by the Shapiro-Wilk test. Subsequently were processed by Kruskal–Wallis one-way analysis of variance to compare independent groups of samples in the STATISTICA 14. Significant differences were assessed at the 95% confidence level ($p < 0.05$).

RESULTS AND DISCUSSION

Chemical analysis of sausages

Chemical analysis (**Table 2**) showed differences in water, protein, fat, and salt content between the products ($p < 0.05$). The water content of the samples decreased as the addition of cricket powder increased. Increasing dry matter and the influence of the structure of the insect powder, meat products can be hard and crumbly and therefore unattractive to the consumer **(Pavelková *et al.*, 2022)**. This was caused by cricket powder water content (2.92 ± 2.20%) which was lower than in meat. The addition of cricket powder is an opportunity to potentially add more water, as the cricket powder could increase the water holding capacity of the products **(Pavelková *et al.*, 2022; Kim *et al.*, 2017)**. On the other hand, the sausages with cricket powder had a higher protein content than the control variant ($p < 0.05$). This was expected as cricket powder contains high levels of protein in dry matter **(Caparros Megido *et al.*, 2016)** and cricket powder was reported to increase protein content in other foods **(Wendin and Nyberg, 2021)**. Due to the high fat content in cricket powder, higher addition caused increasing trend of fat content ($p < 0.05$). In the case of fat, the highest average content was analysed in CP12, which was 3.66% higher than C ($p < 0.05$).

Table 2 Chemical analysis of sausages with cricket powder (g.100 g^{-1})

	C (x̄ ± SD)	CP3 (x̄ ± SD)	CP6 (x̄ ± SD)	CP12 (x̄ ± SD)
Water	57.75 ± 0.49^{a}	53.74 ± 0.28^{b}	50.89 ± 0.19^{c}	45.18 ± 0.16^{d}
Protein	17.99 ± 0.38^{d}	19.21 ± 0.06^{c}	22.89 ± 0.34^{b}	25.37 ± 0.04^{a}
Fat	21.09 ± 0.46^{c}	21.95 ± 0.33^{c}	22.96 ± 0.17^{b}	24.75 ± 0.16^{a}
NaCl	2.20 ± 0.02^{a}	2.14 ± 0.03^{a}	2.02 ± 0.02^{b}	1.92 ± 0.01^{c}

Legend: C=without cricket powder, CP3=with 3% addition of cricket powder, CP6=with 6% addition of cricket powder, CP12=with 12% addition of cricket powder, x̄±SD – average ± standard deviation, Values with different superscripts in the same row indicate significant differences ($p < 0.05$).

Colour measurement of sausages

Colour (**Table 3**) is one of the most important characteristics of meat products. It has a major influence on consumer preference. The colour of the surface of a meat product had a significant impact on the consumer's decision to buy, meaning that a product can be rejected on the basis of colour alone, even before other characteristics are assessed **(Jůzl *et al.*, 2019)**. Insect powders can affect the colour of meat products in several ways, depending on the type of insect used. Mealworm (*T. molitor*) larvae powder can change the colour of products due to its distinctive yellow colour, and banana cricket (*G. assimilis*) powder has a dark brown colour, cricket powder (*A. domestica*) has a characteristic yellow-brown colour **(Oliveira *et al.*, 2024).** The value of the *L** parameter decreased with the amount of cricket powder added ($p < 0.05$). This reduction was observed both on the surface and in the cut, even with the naked eye. In both cases, the most significant difference ($p < 0.05$) was observed between the C and CP12. On the surface, there was also a decrease in the *a** and *b** coordinates. This change in surface colour was also reflected in the sensory evaluation (**Figure 1**), with individual sausages scoring lower on the overall appearance descriptor as the amount of cricket powder increased ($p < 0.05$). On cut, there was a significant difference, particularly in the *L** values, as the product darkened with increasing amounts of cricket powder, as was the case with the surface colour ($p < 0.05$). Parameter *b** (yellowness) also increased in CP6 and CP12 on cut ($p < 0.05$).

Table 3 Colour measurement of sausages with cricket powder

	C (x̄ ± SD)	CP3 (x̄ ± SD)	CP6 (x̄ ± SD)	CP12 (x̄ ± SD)
*L** (surface)	50.17 ± 2.20^{a}	39.47 ± 2.21^{b}	37.62 ± 0.68^{b}	34.37 ± 2.13^{c}
*a** (surface)	13.11 ± 1.44^{a}	13.15 ± 0.63^{a}	10.22 ± 0.72^{ab}	9.33 ± 0.17^{b}
*b** (surface)	28.46 ± 1.30^{a}	21.79 ± 1.75^{b}	18.52 ± 0.37^{b}	17.70 ± 1.62^{b}
*L** (cut)	62.03 ± 1.69^{a}	53.20 ± 3.00^{b}	47.20 ± 1.72^{c}	45.31 ± 0.72^{c}
*a** (cut)	6.75 ± 0.41	6.78 ± 1.16	7.52 ± 1.09	5.89 ± 1.22
*b** (cut)	8.73 ± 0.63^{a}	8.84 ± 0.93^{a}	9.53 ± 0.46^{b}	10.61 ± 0.45^{b}

Legend: C=without cricket powder, CP3=with 3% addition of cricket powder, CP6=with 6% addition of cricket powder, CP12=with 12% addition of cricket powder, x̄±SD – average ± standard deviation, Values with different superscripts in the same row indicate significant differences ($p < 0.05$).

Texture measurement

Analysis of textural properties (**Table 4**) by MORS method showed no significant differences between sausages variants ($p > 0.05$). The cohesiveness is technologically important for the disintegration of the product. The results show that the addition of cricket powder did not negatively affect the consistency of the product. However, the sensory evaluators found differences in the acceptability of tenderness descriptor.

Table 4 Shear force of sausages with cricket powder (N)

	C (x̄ ± SD)	CP3 (x̄ ± SD)	CP6 (x̄ ± SD)	CP12 (x̄ ± SD)
Shear force	20.31 ± 3.88	19.31 ± 2.72	21.89 ± 3.15	23.81 ± 3.42

Legend: C=without cricket powder, CP3=with 3% addition of cricket powder, CP6=with 6% addition of cricket powder, CP12=with 12% addition of cricket powder, x̄±SD – average ± standard deviation, Values with different superscripts in the same row indicate significant differences ($p < 0.05$).

Sensory evaluation

For all hedonic descriptors (**Figure 1**, **Figure 2**), C scored the highest, and as the amount of cricket powder increased, the scores of sausages with cricket powder added decreased ($p < 0.05$) except odour where no significant differences were found ($p < 0.05$). On the contrary, the intensity of the nutty flavour increased ($p < 0.05$). This means that as the amount of cricket powder increased, all descriptors were negatively affected. **Pavelková *et al.* (2022)** found no significant differences between samples of sausages, but they used lower amount of cricket powder up to 4%. CP12 had the lowest scores on all hedonic descriptors. Despite the lowest score compared to C, where CP12 was rated up to 40 points lower, most descriptors had an average score of above 50 points, which was considered neutral. There was no significant difference ($p < 0.05$) between variants C and CP3 in any of the descriptors, although the average score was lower in the CP3 sample. Thus, the addition of cricket powder in the amount of 3% did not significantly affect the sensory properties of sausages. These results were consistent with **Pavelková *et al.* (2022)** who found no significant differences between sausages with 2% and 4% addition of cricket powder. The appearance of variants decreased with increasing amount of cricket powder. The same decreasing trend was observed for colour in the sensory evaluation. Colour on surface showed significant difference between C and CP12 ($p < 0.05$). On cut, there was a significant difference between C, CP6 and CP12 ($p < 0.05$). No statistically significant difference was found for the odour descriptor ($p > 0.05$). Although the average odour rating decreased with the amount of cricket powder, it did not fall below 80, which means that the odour was still pleasant. Similar results reported by **Caparros Megido *et al.* (2016)**. However, the pleasantness of the odour is highly subjective due to the standard deviation. The addition of 3% cricket powder did not affect the taste of sausages significantly ($p > 0.05$). A higher amount of cricket powder significantly reduced taste acceptability of CP6 and CP12 compared to C ($p < 0.05$). A decreasing trend in taste was also found by **Cavalheiro *et al.* (2023)** in sausages with 7.5% cricket powder added.

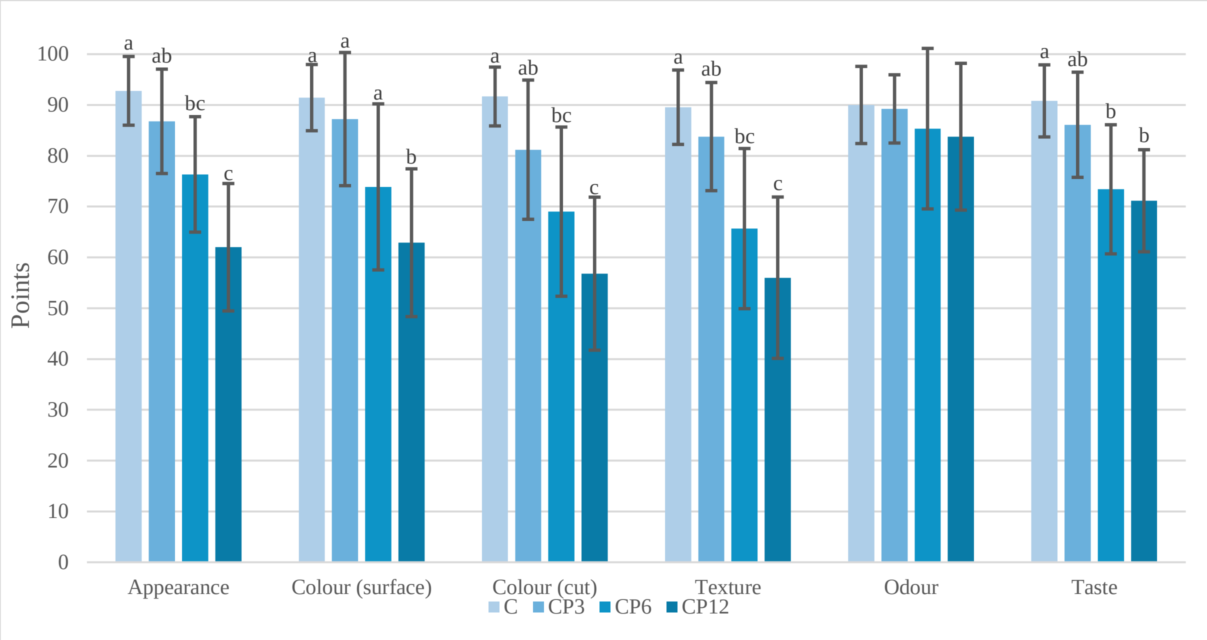

Figure 1 Sensory evaluation of sausages with cricket powder (part 1)
Legend: C=without cricket powder, CP3=with 3% addition of cricket powder, CP6=with 6% addition of cricket powder, CP12=with 12% addition of cricket powder, average with standard deviation, Values with different superscripts indicate significant differences ($p < 0.05$).

Unfortunately, the addition of cricket powder causes an unpleasant sandiness in meat products. The ground chitin content in the cricket powder, makes the sausages feel like sand in the mouth. Variant C had no sandiness at all, and as the amount of cricket powder increased, acceptance of the sausages rapidly decreased. For the CP12 sample, the average acceptance of sandiness was around 42 points. This was the only descriptor to score below 50 points in at least one of samples. On the other hand, the intensity of the nutty taste increased, and for consumers who like this sensation, sausages with cricket powder could be an interesting addition to the diet. Juiciness acceptance was highest in the control sample. Sample CP3 had a lower but still relatively high acceptance, and no significant differences were found compared to the control ($p > 0.05$). The addition of cricket powder also increases the dryness of these products, not only in terms of chemical composition, which was reflected in a lower score for the juiciness descriptor. Significant differences in juiciness were found between C and CP6 and between C and CP12 ($p < 0.05$). Overall liking followed the other hedonic descriptors and showed a decreasing trend of acceptance in sausages with increasing cricket powder addition. Compared to control significant differences were found only in samples with higher amount of cricket powder CP6 and CP12 ($p < 0.05$). This showed the need for further modifications of insect products to improve their sensory properties, as suggested by **Cavalheiro *et al.* (2023)**.

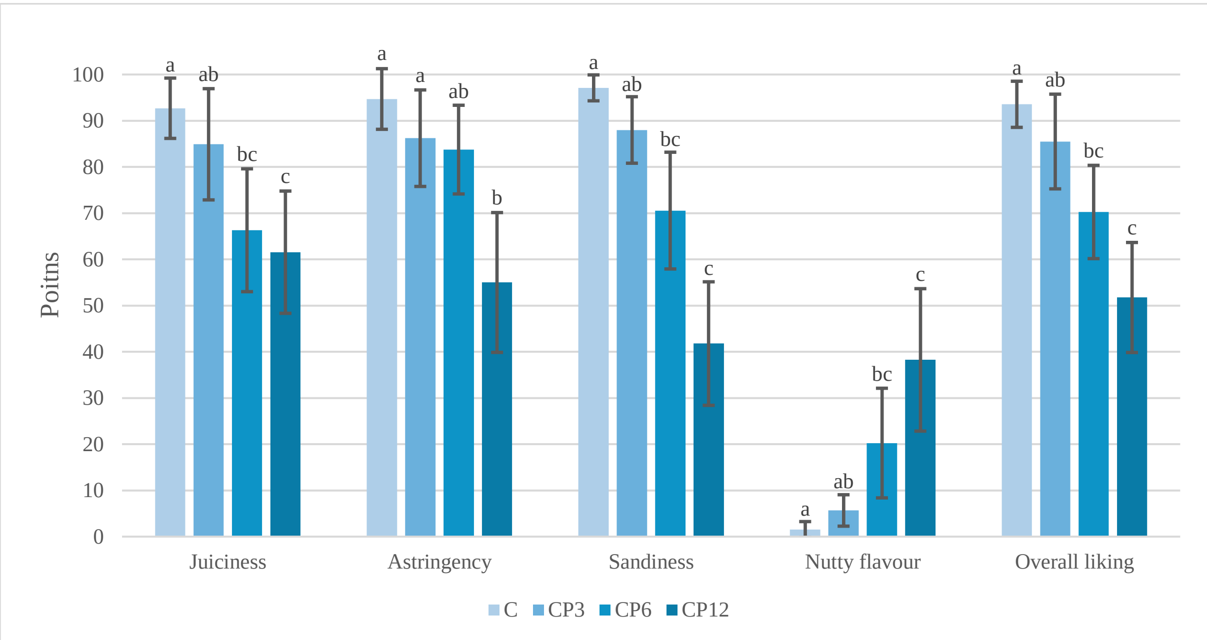

Figure 2 Sensory evaluation of sausages with cricket powder (part 2)
Legend: C=without cricket powder, CP3=with 3% addition of cricket powder, CP6=with 6% addition of cricket powder, CP12=with 12% addition of cricket powder, average with standard deviation, Values with different superscripts indicate significant differences ($p < 0.05$).

CONCLUSION

The addition of cricket powder affected the chemical composition of the sausages leading to an increase in both fat and protein content. The colour of the sausages, both on the surface and on the cut was also affected. As the addition of cricket powder increased, the product became darker. In terms of textural properties, no significant differences in shear force were found. Sensory evaluation revealed that the sausages with the lowest addition of cricket powder (3%) were comparable to the control, while the other variants received negative evaluations, especially for the descriptors such as sandiness and astringency. The intensity of the nutty taste increased, and for consumers who like the nutty taste, sausages with cricket powder could be an interesting option. Based on these results, it can be concluded that cricket powder can be used at a level at 3% in sausages without negative impact on sensory quality.

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