DEVELOPMENT AND PHYSICOCHEMICAL EVALUATION OF CRACKERS WITH *CERATITIS CAPITATA* LARVAL FLOUR: NUTRITIONAL IMPACT AND TECHNOLOGICAL POTENTIAL

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ABSTRACT – Insects are potential food ingredients due to their nutritional characteristics and low environmental impact. However, food neophobia still hinders their acceptance. Therefore, incorporating them into widely consumed foods, such as crackers, can facilitate their market introduction. The aim of this study was to add *Ceratitis Capitata* larva flour to crackers (CI), replacing part of the wheat flour, and evaluate its nutritional, physicochemical, and technological properties, as well as baking performance. CI showed a higher expansion factor, cooking loss, and fracturability than the control crackers. Although CI had a higher lipid content, it still had a lower caloric value. This study demonstrated that insect flour exhibits positive technological properties, with nutritional aspects improving for its use as a promising food ingredient in bakery products.

KEYWORDS: baking; edible insects; technological properties.

1. INTRODUCTION

Edible insects have significant potential to mitigate food crises owing to their diversity, abundance, and low environmental impact, especially when large-scale production is considered (Zhang *et al.* 2022). According to Van Huis and Rumpold (2021), an effective approach to promote insect consumption is to integrate them into traditionally accepted and widely consumed food products, it is a way that their presence is less noticeable while ensuring a pleasant taste. Therefore, it is essential to evaluate their potential as food ingredients. Crackers have been gaining increasing popularity as bakery products in developing countries, due to their various attractive qualities, such as desirable taste and longer shelf life (Fernandes *et al*. 2025).

Ceratitis capitata, known as the Mediterranean fruit fly, reproduces directly on fruits and feeds on plant material throughout its life cycle (Cartaxo *et al.* 2022). This feeding behavior results in larvae with a more neutral and less distinctive taste than other species, making it an interesting option for food applications. Thus, this species has great potential for use as an edible insect and as a new species to be explored. In light of this, the aim of this study was to develop crackers by replacing part of the wheat flour with *Ceratitis Capitata* larva flour and evaluate their nutritional, physicochemical, and technological properties to understand their performance in baking.

2. MATERIAL AND METHODS

2.1 Material

C. capitata larvae were kindly provided by Nui Insect Science (Pelotas, Brazil), a company certified by the Ministry of Agriculture, Livestock, and Supply (MAPA). The insects were reared according to sanitary standards for human and animal consumption. The killing and drying methods were performed at the Food Technology Laboratory (LTA).

The ingredients for crackers: wheat flour, soybean oil, salt, chemical baking powder, and sugar were purchased from local commerce. All reagents used in the chemical analyses were of analytical grade.

2.2 Methods

Preparation of larval flour: The larvae were euthanized via freezing at -18 °C for 24 h, followed by oven drying at 60 °C for 24 h. The dried insects were then ground using a knife mill The resulting insect flour was stored in sealed polyethylene containers at room temperature until use.

Preparation of crackers: Crackers were prepared according to Fernandes et al. (2025). The cracker formulations are presented in Table 1.

Table 1 – Formulation of crackers

	CC	**CI**
Wheat flour (g)	110	90
Ceratitis Capitata flour (g)	-	20
Sugar (g)	7.5	7.5
Salt (g)	3	3
Baking powder (g)	5	5
Soybean oil (mL)	10	10
Water (mL)	50	50

CC: Control Cracker; CI: Cracker with insect.

Proximate composition and caloric value: The determination of moisture (No. 960.39), ash (No. 923.03), and protein using the Kjeldahl method (No. 992.15), with a conversion factor of 5.6 for insects and lipids using the Soxhlet method (No. 925.30), was performed according to AOAC (2000). Carbohydrates were obtained by difference. The caloric value of the crackers was determined according to Watt and Merrill (1963), using the caloric coefficients of proteins, carbohydrates, and lipids, as described in Equation 1.

$$\text{Caloric value (kcal} \cdot 100\ \text{g}^{-1}) = (\text{g of protein} * 4) + (\text{g of lipids} * 9) + (\text{g of carbohydrates} * 4) \quad (1)$$

Physical characteristics: The physical characteristics as the, expansion factor and losses on baking of the crackers, were evaluated according to the AACC (2000) method 10-50D. The expansion factor was determined based on the relationship between the diameter and thickness of the cookie after baking. The crackers were evaluated for mass loss during baking, which is related to the mass of the crackers before and after baking.

Texture and color: The texture of crackers was evaluated based on firmness and fracturability using a TA-XT2 texture analyzer (Stable Micro Systems, UK). The procedure involved compressing 10 crackers at the center of the platform with a cylindrical probe HDP/3PB under the following conditions: pre-test speed: 1.0 mm·s^{-1}; test speed: 3.0 mm·s^{-1}; post-test speed: 10.0 mm·s^{-1}; distance: 5 mm; trigger force: 50 g. Firmness was expressed in Newtons (N), and fracturability in millimeters (mm). The color of crackers was determined using a colorimeter (Minolta, model CR400, Japan). The analysis was based on the CIE L*ab** system, which was defined by the International Commission on Illumination (CIE) in 1976 to determine the values of L* (lightness), a*, and b* (chromaticity coordinates). The hue angle or h° was also calculated, applying the arctangent function to the ratio between the value $b*$ and the value $a*$.

Statistical analysis: All determinations were performed in triplicate. The data were compared using analysis of variance (ANOVA), and the mean values obtained were compared using Student's t-test, considering a significance level (α) of $p < 0.05$.

3. RESULTS AND DISCUSSION

Table 2 presents the proximal composition of the control and crackers with insects; the moisture content between the samples differed significantly, with the crackers with insects showing a higher value. However, the moisture levels found in both formulations were within the standards established by Brazilian legislation (Resolution - CNNPA No. 12 of 1978) for crackers, which stipulates a maximum allowable moisture of 14% (BRASIL, 1978).

Table 2 - Proximal composition and caloric value formulation of crackers

	CC	**CI**
Moisture	$2.86^{b} \pm 0.33$	$6.96^{a} \pm 0.21$
Protein*	$16.64^{a} \pm 0.56$	$12.30^{b} \pm 0.08$
Lipids*	$0.92^{b} \pm 0.17$	$8.22^{a} \pm 0.29$
Ash*	$5.35^{b} \pm 0.11$	$6.18^{a} \pm 0.27$
Carbohydrates*	74.44	66.52
Caloric value (kcal/100 g)	372.60	389.26

CC: Control Cracker; CI: Cracker with insect. *Dry basis. The average of three values with standard deviation, same letter in the line indicates that there is no significant difference between the means by the t-Student test ($p>0.05$).

Regarding the proteins, the control crackers showed a higher value (16.64%), but this reduction in protein content in the crackers with insects may be related to the proportion of insects used, indicating a need for a higher substitution percentage. The crackers with insects exhibited a significant increase (8.22%) in lipids, while the control had only 0.92%, reflecting the intrinsic composition of insect flour, which is naturally rich in lipids, particularly essential fats and fatty acids, which are important for the nutritional value of the product. The ash content was also higher in the crackers with insects (6.18%), indicating an increase in minerals.

In terms of carbohydrates, the cracker containing insects showed a reduction (66.52%) compared to the control (74.44%), possibly due to the higher lipid content in the insect-based sample. Finally, the caloric value of the crackers with insects was slightly higher than that of the control, reflecting the higher lipid content in the cracker formulation, contributing to a higher energy value. These differences indicated that the inclusion of insects significantly affected the nutritional composition and energy value of the final product. In the field of baking, there are no studies on the application of *Ceratitis Capitata*, therefore, further research is necessary. Table 3 presents the physicochemical, technological, and color parameter evaluations of crackers.

Table 3 - Physical-chemical and technological evaluation formulation of crackers

		CC	**CI**
Expansion factor		6.45 ^{a} ± 0.07	6.29 ^{a} ± 0.18
Losses on baking (%)		33.00 ^{b} ± 0.61	36.73^{a} ± 0.79
Firmness (N)		70.66 ^{a} ± 0.66	44.43 ^{b} ± 2.20
Fracturability (mm)		0.78 ^{b} ± 0.09	1.26 ^{a} ± 0.59
Color	L*	74.59 ^{a} ± 0.36	67.06 ^{b} ± 1.03
	a*	11.03 ^{a} ± 0.33	8.05 ^{b} ± 0.26
	b*	37.54 ^{a} ± 2.63	30.74 ^{b} ± 0.72
	hº	73.83	75.38

CC: control cracker; CI: cracker with insect. L*: lightness; a* and b*: chromaticity hº: hue angle. The average of three values with standard deviation, same letter in the line indicates that there is no significant difference between the means by the t-Student test (p>0.05).

The expansion factor of crackers showed no significant difference between the two formulations, indicating that it did not cause alterations in the dimensions (thickness and diameter). However, regarding the loss during baking, the CI showed a higher loss during the baking process, altering the yield by 3.7%, suggesting that the insect flour absorbed a higher water content.

In terms of texture, CI showed lower firmness and greater fracturability than CC. This suggests that the addition of insects to the cracker formulation resulted in a softer product with greater ease of fragmentation.

Color is an attribute that, in baked products, is influenced by the Maillard reaction and caramelization, which represent the main chemical transformations occurring during the baking process (Fernandes and Salas-Mellado 2017). According to the results in Table 3, TC differed significantly in all colorimetric parameters, tending to a less luminous color with a lower intensity of red and yellow than CC. The hue angle of the crackers was similar and approached a yellow color (90º).

4. CONCLUSIONS

A cracker was developed by replacing part of the wheat flour with *Ceratitis Capitata* larva flour in the formulation. The insect flour-added crackers exhibited important characteristics such as a higher lipid content, lower firmness, and greater fracturability compared to the control crackers, presenting promising results in the baking sector, as the product becomes softer and more easily fragmentable, indicating that the addition of *Ceratitis Capitata* larva flour to the crackers holds great potential as a new raw material and a food ingredient. Further studies are needed to better explore these formulation possibilities. Future research could investigate increasing the substitution level or using degreased flour to improve the nutritional profile of insect crackers.

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