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TECHNOLOGICAL AND SENSORY PROPERTIES OF SPONGE CAKES CONTAINING CRICKET FLOUR (*ACHETA DOMESTICUS*)

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ABSTRACT

Insects are exotic alternative protein source with huge potential for food industry by high nutritional value and limited environmental footprint. The aim of this study is to explore the colour characteristics, technological and sensory properties of sponge cakes enriched with cricket 5% and 10% cricket flour (CF_5C and $CF_{10}C$), used as substitute of the wheat flour. Moisture, pH, a_w, springiness and specific volume decrease with increasing CF in a dose depend manner. Replacement of 10% cricket flour showed negative effect on the colour characteristics, shrinkage, specific volume, springiness and texture of sponge cakes. In $CF_{10}C$ a* shows highest values, while L* and b* present the lowest indications in comparison to other samples measured. The sensory panel found nonspecific taste and off-flavour in 10% CF based sponge cakes. Replacement of wheat flour with up to 5 % CF has slight effect on the sensory properties (appearance, cell siz uniformity, crumb tenderness, odour and taste) of sponge cakes and can successfully be used as innovative ingredient to enhance the protein content in bakery products.

1.Introduction

Pastries are most often made from wheat flour and are characterized by small amount of natural bioactive components. This leads to trade-offs in the quality of the finished product in terms of nutrition and health. The use of dietary fibres from various sources partially replaces wheat flour and contributes to the added value to those products (Anonymous, 2001).

Nowadays, food industry pays increasing attention to insects and insect flours as an alternative protein source with high nutritional value. Some beneficial aspects of insect usage are the significant content of protein, vitamins, and minerals and limited environmental footprint (Smarzyński *et al.* 2019). Insect consumption in Africa, Australia and Latin America has a long history (Melgar - Lalanne *et al*., 2019). Cricket flour (*Acheta domesticus*) is a good source of protein (da Rosa and Thys, 2019). It has good water- and fat- retaining properties and at the same time is a rich source of micro- and macro- elements (Biró *et al.*, 2020).

FAO report recommends the use of insect products as they are a rich source of protein and an alternative to tackling the growing population, respectively the growing hunger.

For the European market, this type of product is exotic and in recent years has been a subject of great interest from consumers (van Huis, 2013). From 1 January 2018, in some European countries, insects, as well as parts of them, are officially authorized for production and sale, such as the so-called "novel foods" (C/2017/8878).

Replacing part of the wheat flour with crickets flour helps to reduce the total gluten content and at the same time improves the amino acid and fatty acid composition of the product (Mishyna *et al.*, 2020). The success of the introduction of exotic foods in the menu of Europeans is associated with the added value and the shown interest that the product brings. However, the region-specific preferences, such as taste and texture, must also be taken into account (González *et al.,* 2019). The amount of the additive should be correctly determined so that the technological and organoleptic characteristics of insect-based food are not impaired (Biró *et al*., 2020).

Therefore, the present study aims to determine the technological, colour and sensory characteristics of sponge cakes processed by 5 and 10% replacing wheat flour with cricket flour (*Acheta domesticus*) in order to improve its nutritional value.

2. Materials and methods

2.1. *Ingredients*

Wheat flour of type 500 (WF), granulated sugar and chicken eggs were purchased from local market. Cricket flour (*Acheta domesticus*) (CF) is provided by Ento sinergy Ltd. The physicochemical parameters of the flours are presented in Table 1.

Table 1. Chemical composition and mineral content of wheat flour (WF) and cricket flour (CF).

Parameters	WF	CF
Dry matter, %	85.70	85.53
Proteins, %	11.57	63.64
Fats, %	1.00	14.43
Carbohydrates, %	88.76	12.90
Energy value, kcal/100g	410.72	436.03
pH	5.20	6.83
Moisture,%	14.30	14.47
Zink, mg/kg	7.40	160.00
Manganese, mg/kg	4.30	36.00
Iron, mg/kg	7.10	60.00
Calcium, mg/kg	0.19	650.00
Sodium, %	0.34	0.43
Magnesium, %	0.02	0.53

2.2.1. Sponge cake preparation

The cake batter was prepared (Table 2) by double mixing procedure with partitioning whipping of whites and yolks of egg (Stankov *et al.*, 2018). The control sponge cake (WFB) formulation contained only wheat flour. In CF_5B and $CF_{10}B$ batter the wheat flour was partially replaced with 5% and 10% CF, resp. After mixing of batter was placed in metallic pans and baked in an electric oven for 30 min at 180 ^oC.

Table 2. Sponge cake batters formulations

Ingredients	Amount based on wheat flour, %		
	Control sample (WFB)	with 5% CF_5B	with 10% $CF_{10}B$
Yolk of eggs	43.22	43.22	43.22
White of eggs	96.77	96.77	96.77
Granulated sugar	83.77	83.77	83.77
Wheat flour type 500	100.00	95.00	90.00
Cricket flour	-	5.00	10.00

2.2. Methods

2.2.1. Specific gravity (batters cakes)

The specific gravity of the sponge cake batter was calculated by dividing the weight of a batter cup to the weight of an equal volume of distilled water (AACC 10-95, 1983).

2.2.2. Colour characteristics

A Konica Minolta colorimeter CR-410 (Konica Minolta Holding, Inc., Ewing, New Jersey, USA) was used to evaluate the brightness (L* value), the red component (a* value) and the yellow component (b* value) (Hunt *et al.* 2012). Total colour difference (ΔE) is calculated:

$$\Delta E = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}, \quad (1)$$

where ΔL*, Δa* and Δb* are the differences in the values of L*, a*, b* between those of the control and the corresponding experimental sample.

2.2.3. pH value determination

The pH value of the samples was measured electropotentiometrically (Osimani et al., 2018) with pH meter "Microsyst MS 2004" (Microsyst, Plovdiv), equipped with temperature and combined pH electrode. The pH electrode is of the Sensorex Combination Recorder S 450 CD type (Sensorex pH Electrode Station, Garden Grove, CA, USA).

2.2.4. World photographic analysis

Sample analysis was performed using a microscope (Olympus BX41TF, Japan) at a magnification of 100x.

2.2.5. Determination of volume of the product

Volume was measured by the small, homogeneous grain displacement method with a volume meter, [cm^3] (Ngo et al., 1986; AACC 10-05, 2000);

2.2.6. Determination of specific volume

It is calculated by the ratio of the volume of the cake to its mass, [cm^3 / g];

2.2.7. Structural and mechanical properties of cakes

Shrinkage [PU] and springness (relaxation) [PU] are determined with an automatic penetrometer (model DS VEB Feinmess, Dresden, Germany) (Stankov *et al., 2018*).

2.2.8. Water activity (a_W)

The water activity of the batter and the crumb samples was determined using a Novasina AG CH-8853 water activity meter (Zurich, Switzerland) at 20 °C.

2.2.9. Moisture content

The moisture content is determined after drying the sample at 104 - 105 ° C till reaching a constant weight AACC 44-15.02. (AACC, 1999).

2.2.10. Water absorption capacity

The water absorption capacity of the cake was measured by the method for determining of biscuits' swelling according to BDS 15221: 1981.

2.2.11. Sensory evaluation

Five member panel group with proven abilities was used to determine the sensory parameters (appearance, cell siz uniformity, crumb tenderness, odour and taste) of the cakes (Meilgaard et al. 1999) was used. The samples were scored using 1 to 5 scales.

2.2.12. Photograph images

For the determination of the sponge cake crumb structure, photographs were taken of the half-cut cake.

2.2.13. Statistical analysis

Statistical analysis of the average values of five time reps was made. All statistical procedures for the data of different samples were analyzed by SAS software (SAS Institute, Inc. 1990). The Student-Newman-Keuls multiple range test was used to compare differences among means. The results were expressed as mean values and standard errors of the mean. A p-value less than 0.05 ($p < 0.05$) was considered as significant.

3. Results and discussions

3.1. Physicochemical characteristics

As a result the water activity of the sponge system correlates to the forms of the bound water. By the slightly acidic reaction of CF, pH in batter decrease with the increase in CF concentration (10%, $CF_{10}B$) (Table 3). According to Osimani *et al.*, 2018 the higher ash content of CF influences the buffering capacity in the matrix and decrease the pH of batter (Mariotti *et al.,* 2014; Taccari *et al.*, 2016).

Table 3. Physicochemical and textural characteristics of sponge batter and cakes

Physicochemical and textural characteristics	Sponge cake type		
	Control sample (WFB)	with 5% CF_5B	with 10% $CF_{10}B$
Specific gravity (for batter)	$0.54^a \pm 0.02$	$0.66^b \pm 0.03$	$0.74^c \pm 0.02$
Volume, cm^3	$210.00^b \pm 3.00$	$210.00^b \pm 2.00$	$200.00^a \pm 1.50$
Specific volume, cm^3/g	$3.44^c \pm 0.06$	$3.28^b \pm 0.05$	$3.18^a \pm 0.06$
pH (for batter)	$7.60^b \pm 0.08$	$7.24^a \pm 0.02$	$7.17^a \pm 0.05$
Moisture, %	$43.37^a \pm 0.55$	$42.13^a \pm 2.09$	$41.56^a \pm 1.34$
a_w, crumb cake	$0.920^b \pm 0.004$	$0.905^a \pm 0.005$	$0.900^a \pm 0.002$
Springiness, [PU[1]]	$118.00^{c,} \pm 2.00$	$97.00^b \pm 1.00$	$74.00^a \pm 1.00$
Shrinkage [PU[1]]	$24.00^{b,z} \pm 1.00$	$25.00^{b,y} \pm 0.50$	$14.00^{a,z} \pm 0.50$
Water-absorbing capacity,%	$388.00^b \pm 3.00$	$310.00^a \pm 2.50$	$306.00^a \pm 3.00$

WFB, cake batter containing 100% wheat flour; CF_5B – cake batter with blend containing 5% cricket flour and 95% wheat flour; $CF_{10}B$ – cake batter with blend containing 10% cricket flour and 90% wheat flour; WFC – sponge cake containing 100% wheat flour; CF_5C, sponge cake with blend containing 5% cricket flour and 95% wheat flour; $CF_{10}C$- sponge cake with blend containing 10% cricket flour and 90% wheat flour.
Results are presented as Means ± Standard error of the means (SEM)
[1]PU - Penetrometer Units.
[a,b,c] Means with different superscripts in each column differ significantly ($p \leq 0.05$) of one parameter

With increasing the amount of CF, the moisture content (Table 3) decreases both in the batter and the cakes ($p \leq 0.05$). At the same time, the highest value ($p \leq 0.05$) for water activity (a_w) was found in the WFB control samples. Water activity (a_w) of control batter (WFB) was 1.63 ($p \leq 0.05$) and 2.17% ($p \leq 0.05$) higher than the samples with 5 and 10% addition of cricket flour (CF_5B and $CF_{10}B$), respectively. The data confirmed previous researches proving that lower water activity result in higher moisture loss (Indriani, 2020). Another possible reason for the established decrease of a_w is the lower moisture content of blended with 5% and 10% CF flour used for preparing the CF_5B and $CF_{10}B$ sponge cakes.

3.2. Textural parameters

The quality of sponge cakes is determined by their baking properties (Table 3). An increase in the relative mass by decrease in the degree of aeration was found in CF enriched cakes ($p \leq 0.05$). The highest degree of shrinkage and springiness characterized the control (WFB) with the highest degree of softness. The CF_5C specific volume, shrinkage and springiness are lower ($p \leq 0.05$), but close to those obtained for WFC. Decreased springiness and more difficult chewing have also been reported by Pauter *et al.*, 2018 in sponge cakes with CF. The mass and bulk between controls (WFB) and CF_5B do not differ significant ($p \leq 0.05$). The data obtained for specific volume (Table 3) did not show a statistically significant ($p \leq 0.05$) difference between the two CF based sponge cakes (CF_5C and $CF_{10}C$). Compared to WFC, the specific volume in CF_5C and $CF_{10}C$ is about 5% ($p \leq 0.05$) lower, which is most likely due to the higher protein content and the lower degree of aeration of the batter. In contrast to our results, González *et al.,* (2019) replaced 5% WF with grounded *Hermetia illucens, Acheta domesitca, Tenebrio molitor* protein and fibre and did not report changes in specific volume in bread. Perhaps the presence of fibre in recipe composition helps to preserve the specific volume and texture of the product.

The deterioration of the parameters relative mass, springiness, shrinkage and specific volume increases with higher amount of CF ($p \geq 0.05$). The shrinkage determines the internal stability of the structure, as it is directly related to the ingredients used in making the batter. The exact amount of insect floor is very important. According to Indriani *et al.* (2020) the starch content is lower in the cakes after wheat replacement. On the other hand, cricket exoskeleton contained 8-9% non-soluble chitin, which is a source of insoluble fibre. Chitin makes foam bubbles unstable and decrease film layer stability. Poor foam properties of CF (*Acheta domesticus*) were reported by Yi *et al.,* (2013). A linear correlation between volume, hardness and insect flour used for processing of cinereous cockroach (*Nauphoeta cinerea*) enriched breads was prooven by de Oliveira *et al.* (2017). The results obtained show that the replacement of WF with CF in an amount of up to 5% has a lower impact on the technological characteristics of sponge cakes.

3.3. Colour characteristics

Blending the wheat flour with cricket flour affected the cake lightness ($p \leq 0.05$). The batter colour lightness (L*) (WFB) was 7.11% and 10.51% higher than that measured after the partial replacement with CP ($p \leq 0.05$). The same trend was established after baking. The L* value of WFC was 8.24 and 12.56% higher ($p \leq 0.05$), compared to the cakes with 5 and 10% cricket flour, respectively (Table 4).

Table 4. Colour indicators of the sponge batters and cakes

	Cake batter			Sponge cakes		
Sample	WFB	CF_5B	$CF_{10}B$	WFC	CF_5C	$CF_{10}C$
L*(C)	$83.80^c \pm 0.06$	$77.84^b \pm 0.06$	$74.99^a \pm 0.01$	$77.83^c \pm 0.12$	$71.41^b \pm 0.06$	$68.05^a \pm 0.13$
a* (C)	$0.91^a \pm 0.18$	$1.30^b \pm 0.01$	$1.47^c \pm 0.01$	$0.91^a \pm 0.03$	$2.17^b \pm 0.04$	$3.08^c \pm 0.05$
b* (C)	$27.91^c \pm 0.58$	$23.54^b \pm 0.02$	$21.06^a \pm 0.04$	$26.10^c \pm 0.08$	$23.79^b \pm 0.11$	$22.34^a \pm 0.16$
ΔE	-	7.46	11.17	-	6.42	10.70

WFB, cake batter containing 100% wheat flour; CF_5B – cake batter with blend containing 5% cricket flour and 95% wheat flour; $CF_{10}B$ – cake batter with blend containing 10% cricket flour and 90% wheat flour; WFC – sponge cake containing 100% wheat flour; CF_5C, sponge cake with blend containing 5% cricket flour and 95% wheat flour; $CF_{10}C$- sponge cake with blend containing 10% cricket flour and 90% wheat flour.
Results are presented as Means ± Standard error of the means (SEM)
^{a,b,c} Means with different superscripts in each column differ significantly ($p \leq 0.05$) of one parameter.

The control sponge cakes (WFC) was lowest in colour redness (a*) ($p \leq 0.05$) and highest in yellow colour component (b*) ($p \leq 0.05$). Both in the batter and in the baked cakes a* increases and b* decreases with higher CF replacement ($p \leq 0.05$). In a similar study of muffins with 5 and 10% CF a* and b* values shifted to the green and blue areas, respectively (Pauter *et al.*, 2018).

When using ingredient for wheat replacement, it is desirable for products to retain their colour characteristics in order to be accepted by the consumers (Biró *et al.*, 2020). The darker colour in CF based cakes is expected, as the cricket flour is darker in colour, too. Decreases in L * values were also obtained in other studies after partial replacement of WF with CF in muffins (Pauter *et al.,* 2018), cricket-Enriched Oat Biscuit (Biró *et al.,* 2020) and in other cricket-based foods (Mishyna *et al.,* 2020). We can conclude that blending the WP with CF should not exceed 5% in order to avoid the colour deterioration of the final product.

It`s reported that deviation in ΔE above 3.5 is a proof for significant difference between two samples (Tkacz et al., 2020). Total colour difference (ΔE) of $CF_{10}C$ is 33% higher compared to ΔE of CF_5C. We can conclude that the replacement of WP with CF significantly changes the total colour difference (ΔE) in a dose-dependent manner ($p \leq 0.05$).

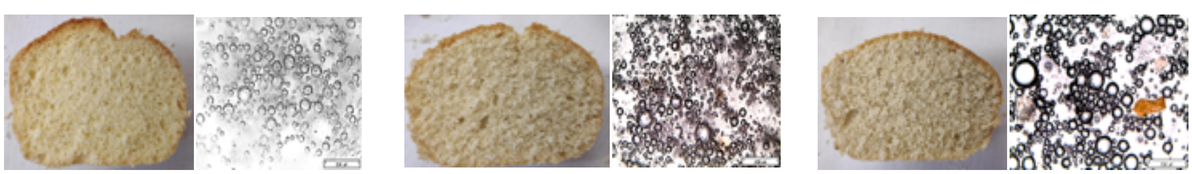
3.4. Sensory analysis

The results of the sensory analysis confirm the data for the relative mass of the batter. The sensory panel also confirms the data on the specific volume of cricket-based cakes, which decreases with increasing amount of CF. It is known that usage of edible insects with hard exoskeletons (crickets, grasshoppers) containing chitin, result in insect based products with soft texture. Even more, the legs and wings of grasshoppers and locusts should be removed before consumption (van Huis et al., 2013). Microscopic photographs of the batter clearly show the presence of solid particles from the chitin shells (Fig.1).

The high dry matter content and the correspondingly lower humidity of CF cakes are another reason for their drier texture.

The best evaluated in terms of appearance, cell siz uniformity, crumb tenderness, odour and taste is the control sample (WFC) followed by 5% cricket-enriched cakes (Fig. 2). Sensory analysis showed that the colour of the outer surface of WFC, CF_5C and $CF_{10}C$ after baking did not differ statistically significantly, but the cell siz uniformity darkened with increasing % of CF replacement. These results are in sync with the colour lightness data (L *) (Table 4).

Control sample (WFC) Sponge cake (CF_5C) Sponge cake ($CF_{10}C$)



WFC – sponge cake containing 100% wheat flour; CF_5C, sponge cake with blend containing 5% cricket flour and 95% wheat flour; $CF_{10}C$- sponge cake with blend containing 10% cricket flour and 90% wheat flour.

Figure.1. Photographs of cross sections of the sponge cakes, and micro photograms of batters

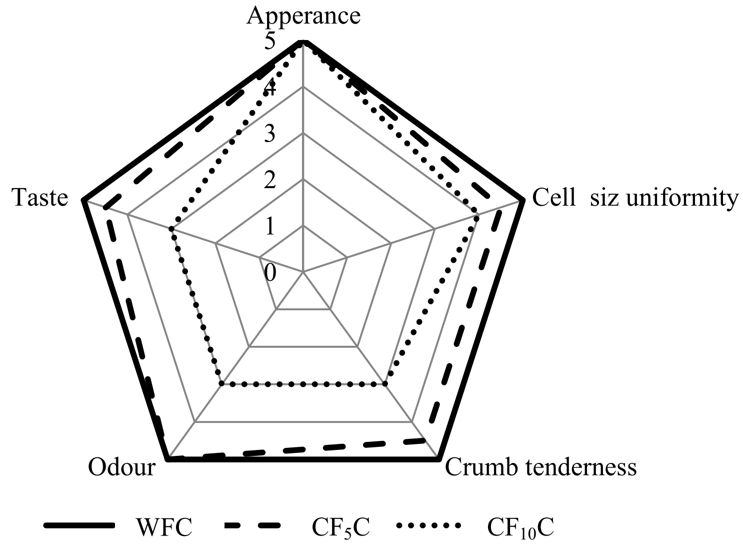


Figure 2. Sensory properties of sponge cakes

After partial replacement of WP with 10% CF, the cakes ($CF_{10}C$) have a visibly smaller volume (Table 3).

The most significant changes were found in the texture of $CF_{10}C$ blended sponge cakes. The results of the sensory analysis were in sync with the data obtained for shrinkage and springiness of the cakes (Table 3). The texture of cricket-based cakes was denser, with an increase in chewing hardness correlated with the amount of CF used. The sensory panel rated $CF_{10}C$ as too dry. A drier consistency has also been reported by Pauter et al., 2018 when adding CF to cakes. According to Kinyuru, Kenji, & Njoroge (2009), replacing WP with ground termite up to 5% does not affect the texture of the products. Apart from the amount, probably the type of insect flour used is another factor determining the maximum percentage used in the product. Although cricket flour does not have a strong specific aroma, $CF_{10}C$ sponge cakes have an uncharacteristic aftertaste, which is the reason for the low taste and smell grades given to $CF_{10}C$.

4. Conclusions

The high nutritional value of edible insects and the interest to that exotic alternative protein source played the attention of food industry as potential food ingredient. Quality characteristics of cricket flour labelled sponge cakes were strongly influenced by CF concentration. Replacement of wheat flour with 5% cricket flour had slight effect on the sensory properties of sponge cakes. Replacement with 10% cricket flour showed negative effect on colour characteristics with highest decrease in L* and a* value, as well as increase in b* value. The shrinkage, springiness and texture characteristics of cakes correlate with CF concentration and decreased significantly in 10% CF based sponge cakes. pH, moisture and a_w decreased in CF blended cakes in a dose-dependent manner. In accordance to the sensory and textural characteristics of CF labelled sponge cakes the cricket flour can successfully be used up to 5% as WF substitute as innovative ingredient to enhance the nutritional value in baked products.

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