Influence of sucrose and barley flour on some physical, texture and sensory characteristics of cookies

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Abstract. The aim of the present paper is to establish the influence of sucrose on the basic properties of the cookies – losses during baking, thickness, volume, specific volume, colour, as well as on their texture and sensory characteristics.
A total of six kinds of cookies were prepared from wheat four, barley flour and mixture of them in ratio 50:50, in two groups according to the sweetener used – with and without sucrose. The results obtained indicated that sucrose and the barley flour exert certain effect on the basic physical properties of the cookies, as well as on their texture and sensory characteristics.
When sucrose is used for preparation of cookies, beside that it imparts sweet taste, the baking losses decreases (13.64 %), thicker cookies are produced (15.95 mm), diameter (68.90 mm), expansion factor (44.43), volume (40 cm^3) and specific volume (1.65 cm^3/g) compared to the cookies prepared without sucrose. The sucrose containing cookies are harder, darker and have more intense red and yellow colour. It was found from the sensory analysis carried out that these cookies are preferred by the consumers.
The addition of barley flour to the cookies composition results in higher loss during the baking but the cookies obtained have bigger diameter compared to these which do not contain barley flour. The cookies prepared from mixture of wheat and barley flour in ratio had the best sensory properties.

1. Introduction

The sweetness of a sweetener depends on many factors: the type of sweetener, its physical state (liquid, crystalline, powdery), as well as the food product to which it is added. When choosing a sweetener for a particular food product, the relative sweetness of the sweetener and its synergistic effects are taken into account [1].

The main sources of sucrose are sugar cane and sugar beet. Sucrose can be used in the form of a solution, crystals or powder. It gives sweetness and color to baked products. Sucrose plays a key role in the formation of the structure of cookies. The amount of sucrose that is part of the recipe of cookies has a significant effect on the gelatinization of starch - the higher the sucrose content, the gelatinization of starch decreases.

Glucose used in the form of glucose solution also imparts sweetness and color to baked goods, like sucrose. It is usually less sweet than sucrose, but is more active in the mayard reaction that occurs during baking. This causes excessive browning of the products and therefore the amount used in the recipe of cookies and other bakery and confectionery products is much less than that of sucrose [2].

Wheat flour is the main raw material in the production of cookies. It contributes mainly to the texture and shape of the cookies [3]. The flour, which contains 8 to 11% protein, is suitable for the production of cookies [4]. Due to the low nutritional value of white wheat flour (type 500), which is widely used for the production of bread, bakery and confectionery, many authors [5-7] consider that by adding barley flour to the composition of products, they can be nutritionally enriched [8]. Barley flour has baking properties similar to rye flour. It contains from 7 to 20% protein. They are not resistant to the action of proteolytic enzymes. They swell slowly and form gluten only under special conditions. Gluten is made into grains that are difficult to stick together and have almost no extensibility [9].

Cookies are mass-consumed products, preferred by different age groups, primarily due to their diverse taste, relatively low price and long shelf life [10]. According to Manley, 2000 [11] cookies can be classified according to: their structure and hardness; the method of forming the dough (lamination, injection molding, extrusion, etc.); the composition of the dough (enriched and unenriched). According to the additional processing after baking, the cookies are: glued with cream; sprinkled or coated with chocolate; covered with various glazes; with the addition of jam and/or jam.

Cookies production is considered an important part of the bakery and confectionery industry, on one hand due to the fast way of production, and on the other - due to the low price. Cookies are most often made from wheat flour, which is a problem for people who pay more attention to their healthy lifestyle including a healthy diet. Therefore, different types of functional cookies can be found on the market today, in which wheat flour is partially or completely replaced by another type of flour [12].

The purpose of this article is to determine the influence of sucrose and barley flour on the basic physical properties of cookies, on their texture and sensory characteristics.

2. Materials and Methods

2.1. Materials

For the production of cookies, the following raw materials were used: wheat flour (Belje d.d. Beli Manastir, Croatia), wholemeal barley flour of the Osvit variety (Agricultural Institute Osijek), as well as margarine, sugar, salt, sodium bicarbonate and glucose, which were purchased from local stores in Osijek, Croatia.

2.2. Methods

The AACC Method 10-50D method was used to prepare the cookies [13]. A total of six types of cookies were obtained - three types without sucrose and three types with sucrose, in order to determine the influence of sucrose on their basic physical properties. To determine the effect of barley flour on the physical properties of cookies, they are produced on the basis of wheat, barley and a mixture of wheat and barley flour in a ratio of 50:50. In the table. 1 shows the recipe composition of the cookies.

Losses observed during firing are calculated according to Šarić (2016) [14].

Thickness, diameter, volume and specific volume were determined using a Volscan Profiler (Stable Microsystems Ltd., Surrey, UK).

The texture characteristics were determined using a TA.XT Plus device (Stable Micro Systems) according to a method presented by Jukić et al., 2018 [15].

The color of the obtained cookies was determined using the Minolta Chroma Meter CR-400 in the CIE L * a * b * model, where the color coordinates are respectively: L * - light / brightness /, L * = 0 - black; L * = 100 - white color; a * - green color (-) / red color (+); b * - blue (-) / yellow (+). The total color change ΔE was calculated according to Nakov et al., 2018 [16].

Sensory analysis of the obtained cookies was performed according to the methodology presented by Yamsaengsung, R., Berghofer, E., & Schoenlechner, R., (2012) [17].

For statistical analysis it was used analysis of variance (ANOVA) and Fisher`s Least Significant Difference test (LSD) at $p<0.05$ were performed with the software XLSTAT 2017 and Microsoft Office Excel 2013.

Table 1. Cookies recipe formulation.

Raw material (%)/ Sample	Sample I	Sample II	Sample III	Sample IV	Sample V	Sample VI
Wheat flour	100.00	50.00	0.00	100.00	50.00	0.00
Barley flour	0.00	50.00	100.00	0.00	50.00	100.00
Sucrose	57.78	57.78	57.78	0.00	0.00	0.00
Shortening	28.44	28.44	28.44	28.44	28.44	28.44
$NaHCO_3$	1.11	1.11	1.11	1.11	1.11	1.11
NaCl	0.93	0.93	0.93	0.93	0.93	0.93
Glucose solution*	14.67	14.67	14.67	14.67	14.67	14.67
H_2O	7.11	7.11	7.11	7.11	7.11	7.11

**Concentration of glucose solution is 5.93 g/L.*

3. Results and discussion

During baking, the physical properties of the cookies change. This is due to the penetration of heat from the oven into the cookies, and the moisture from the cookies passes into the oven [9,19]. Table 2 presents the baking losses and the physical characteristics (thickness, diameter, volume and specific volume) of the cookies obtained.

Table 2. Physical properties of cookies.

Physical properties	Cooking loss (%)	Width (mm)	Thickness (mm)	Spread factor (W/T x 10)	Volume (cm^3)	Specific Volume (cm^3/g)
Sampe I	$13.03^{c} \pm 0.02$	$65.55^{c} \pm 0.92$	$18.30^{a} \pm 0.14$	$35.82^{c} \pm 0.78$	$42.50^{a} \pm 0.71$	$1.79^{a} \pm 0.02$
Sampe II	$13.07^{c} \pm 0.10$	$67.40^{b} \pm 1.13$	$16.50^{b} \pm 0.57$	$40.86^{b} \pm 0.72$	$41.00^{a} \pm 1.41$	$1.64^{b} \pm 0.06$
Sampe III	$14.82^{b} \pm 0.01$	$73.75^{a} \pm 0.21$	$13.05^{d} \pm 0.78$	$56.61^{a} \pm 3.21$	$36.50^{b} \pm 0.71$	$1.53^{c} \pm 0.05$
Sampe IV	$12.33^{e} \pm 0.04$	$55.70^{f} \pm 0.71$	$15.20^{b,c} \pm 0.00$	$39.87^{b,c} \pm 0.28$	$28.00^{c} \pm 0.00$	$1.12^{d} \pm 0.01$
Sampe V	$12.70^{d} \pm 0.03$	$58.05^{e} \pm 0.07$	$14.00^{c,d} \pm 0.85$	$39.84^{b} \pm 1.91$	$28.00^{c} \pm 0.00$	$1.10^{d} \pm 0.00$
Sampe VI	$19.39^{a} \pm 0.04$	$60.60^{d} \pm 0.42$	$12.75^{d} \pm 0.64$	$45.59^{b} \pm 2.33$	$25.00^{d} \pm 0.00$	$1.09^{d} \pm 0.00$

Values are means SD ($n \geq 5$); values in the same row with different exponents have statistically significant differences ($p < 0.05$) following Fisher's LSD test.

The data presented in Table 2 show that the baking losses of different types of cookies increase when barley flour is added to the cookies composition. On the other hand, it is evident that with cookies with sucrose, the losses are lower. Nakov, 2017 in his research has found the same trend of increasing losses when baking in sucrose-free cookies [20]. Sharma and Gujral, 2014 believe that the reduction in baking losses due to the replacement of wheat with barley flour is due to the greater water holding capacity of the soluble and insoluble fibers naturally present in barley flour [4].

The ANOVA (not presented) highlighted significant differences ($p < 0.05$) in cooking loss of cookies.

Sucrose-free wheat cookies have the smallest diameter (55.70 mm). It can be observed that the diameter of the cookies increases with increasing amount of barley flour in the composition of the cookies. On the other hand, it can be observed that the lack of sucrose causes a reduction in the diameter of the cookies. One of the reasons for the larger diameter could be the undissolved sucrose when kneading the dough, which completely dissolves during the baking of the cookies, and thus contributes to increasing their diameter [21].

It can be seen from the results presented in Table 2 that the greatest thickness had the cookies made of 100% wheat flour and sweetener sucrose - 18.30 mm, and the smallest - 12.75 mm for cookies with 100% barley flour without sucrose. It can be seen that as the amount of barley flour in the cookies increases, the thickness decreases. On the other hand, the lack of sucrose leads to the production of cookies with a smaller thickness. The ANOVA (not presented) highlighted significant differences ($p < 0.05$) in thickness.

The change in the diameter and thickness of the cookies also affects the expansion factor. A significant increase in the values for the expansion factor is observed when there is a partial or complete replacement of wheat flour with barley, in the presence of sucrose. On the other hand, when there is no sucrose in the composition, the thickness of the cookies decreases slightly.

By measuring the volume of a product, important information about its quality can be obtained [2]. The ANOVA (not presented) highlighted significant differences ($p < 0.05$) in volume of cookies. Table 2 shows that cookies with sucrose have a larger volume than cookies without sucrose. Wheat cookies with sucrose have the largest volume (42.50 cm^3), and barley cookies without sucrose - the smallest (25.00 cm^3). On the other hand, replacing wheat flour with barley flour reduces the volume of cookies. This trend is expected and characteristic of cookies produced by partially replacing wheat with barley or other types of flour that are gluten-free or low in gluten. Wheat flour contains the largest amount of gluten, which gives volume to a product [9].

The specific volume of cookies is a value that is calculated as the ratio between the mass and volume of a cookies. The ANOVA (not presented) highlighted significant differences ($p < 0.05$) for specific volume of cookies. Cookies with sucrose are observed to have a higher specific volume. On the other hand, replacing wheat flour with barley flour reduces the specific volume of cookies. The same has been found by other authors [22-23].

The texture combines all the mechanical, geometric and surface properties of the product [23]. Fig. 1 presents the textural characteristics of the produced cookies. Rupture force represents the force required to break the cookies at certain distance and could be used to describe cookie flexibility and fracturability, as well as cookie hardness. Rupture force decreased with lower levels of added sucrose. Similar results was obtained in research of the role of sugar and fat in sugar-snap cookies [24]. The strength required to break a cookies (fig. 1a) ranges from 41.24 N (for cookies made from 100% wheat flour with sucrose) to 43.82 N for the same type of cookies without sucrose. It can be seen that when the cookies do not contain sucrose, they have higher values for rupture force. The same cookies (without sucrose) also have higher values for snapping distance. The values for this parameter decrease when wheat flour is partially or completely replaced by barley flour. The snapping index of cookies with sucrose show higher values compared to those without sucrose. The values for the hardness parameter decrease with partial or complete replacement of wheat flour with barley flour. Even lower values for this parameter are reported when there is no sucrose in the formulation. Gupta et al. (2011) studied the hardness of cookies with the addition of barley flour and found that with increasing amount of hardness decreases [25].

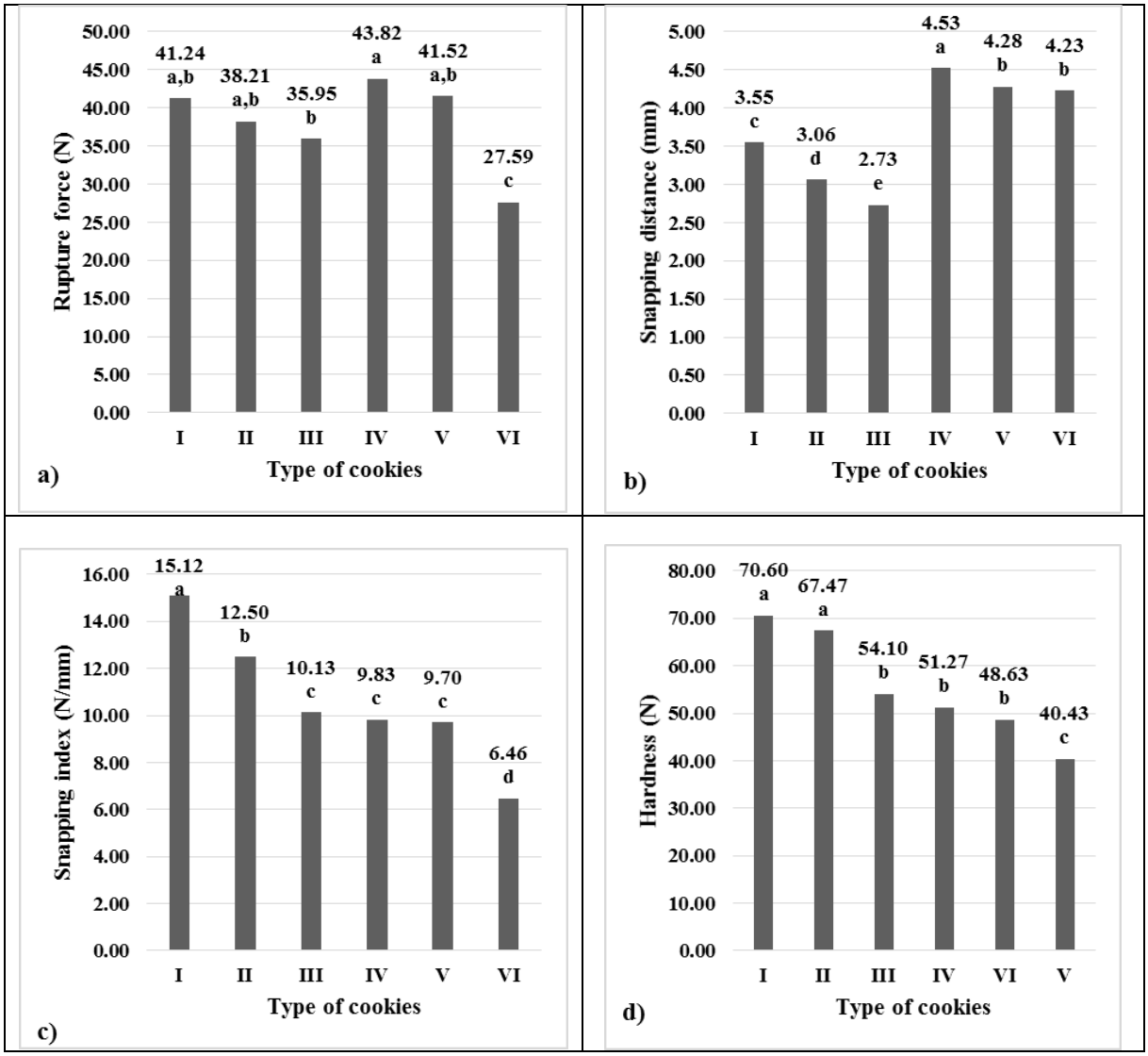

Figure 1. Textural characteristics of cookies.

Baking is a complex process in which complex physicochemical and colloidal changes occur in the dough, which are important for the quality of the final product. During baking, the dough changes its appearance, size, structure, taste and aroma [26]. Colour is the first sensory mark that the user perceives [18]. Table 3 presents the colour data of the obtained cookies.

Table 3. Colour of cookies.

Sample	L*	a*	b*	ΔE
I	$64.03^{a} \pm 0.64$	$6.01^{b} \pm 0.91$	$29.32^{d} \pm 0.53$	-
II	$62.01^{b} \pm 0.44$	$8.32^{a} \pm 0.15$	$31.73^{b} \pm 0.29$	3.9 ± 0.87
III	$56.97^{c} \pm 0.19$	$9.07^{a} \pm 0.39$	$36.71^{a} \pm 0.71$	10.9 ± 0.94
IV	$55.73^{c} \pm 0.45$	$5.31^{b} \pm 0.15$	$25.58^{c} \pm 0.16$	9.2 ± 0.64
V	$55.64^{c} \pm 0.21$	$5.96^{b} \pm 0.09$	$26.95^{e} \pm 0.08$	9.1 ± 0.19
VI	$54.06^{d} \pm 1.15$	$6.27^{b} \pm 0.04$	$30.36^{f} \pm 0.15$	10.1 ± 1.86

Values are means SD ($n \geq 5$); values in the same row with different exponents have statistically significant differences ($p < 0.05$) following Fisher's LSD test.

It can be seen from the results presented in Table 3 that the data for the parameter L * of the cookies with sucrose are higher in comparison with the data of the cookies which do not contain sucrose. In addition, it can be seen that the partial or complete replacement of wheat flour with barley leads to a decrease in the values of the parameter L *, ie. the cookies become darker.

The parameter a * gives information about the red or green color of the cookies. All types of cookies have positive values which means that they have a red color. On the other hand, it can be seen that sucrose cookies have higher values of this parameter, i.e., the red color is more pronounced in them than in the cookies without sucrose. The data from table 3 shows that barley flour enhances the red color of the cookies.

The values for the parameter b * give information about blue or yellow color. It can be seen that the data of all cookies are positive, i.e., the cookies are yellow. Sucrose and barley flour enhance the yellow color of the cookies. According to Nakov, 2017 only cookies with sucrose and 50% replacement of wheat flour with barley are in the group of products with a visible difference (from 3 to 6) [17]. All the other cookies belong to the group with large differences in the color of wheat cookies and other types (> 6).

Sensory analysis in the food industry, to a greater or lesser extent, plays a significant role in the history of food production and sales. It is a scientific discipline that interprets the reactions to these ingredients in food that are perceived by the senses: color, smell and taste [28-29]. Fig. 2 presents the estimates from the performed sensory analysis.

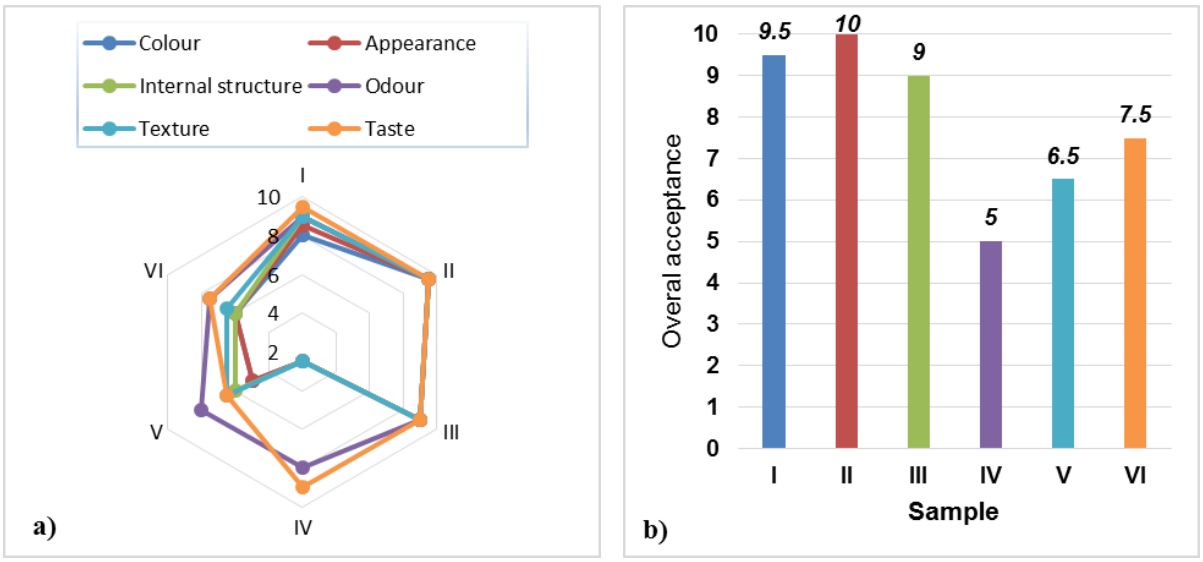

Figure 2. Sensory analysis of cookies.

Fig. 2a shows that the least points for the indicators: color, appearance, brittleness and structure, were obtained by wheat cookies without sucrose (2.5 points out of 10 points). Sugar-free barley cookies were rated as having the worst odor (7.5 points out of 10 points). For the taste indicator, the least points were given to the cookies from 50% wheat and 50% barley flour without sucrose (6.5 points out of 10 points). On the other hand, the best overall score is the wheat-barley cookies with sucrose (fig. 2b), evaluated on the indicators color, appearance and shape, brittleness, smell, structure and taste.

4. Conclusion

It was found from the research carried out that sucrose and barley flour affect the basic physical properties of cookies, their texture and sensory characteristics, namely:

- In the presence of sucrose, the cookies have less baking losses; greater thickness, diameter, expansion factor, volume and specific volume. From the texture characteristics, the cookies with sucrose have

higher values for rupture force , snapping index and hardnes, and lower values for the parameter - snapping distance. The cookies are darker in color and brighter in red and yellow. Sensory evaluation shows greater preference for the consumption of cookies with sucrose than without sucrose.

- When replacing wheat flour with barley, the baking losses, the diameter and the expansion factor of the cookies increase. The values for the thickness, volume and specific volume of the cookies are lower. The values for rupture force , snapping distance, snapping index and hardness decrease. The cookies, which contain barley flour, are also darker in color and brighter in red and yellow. Sensory, wheat-barley cookies with sucrose have the highest overall rating.

Acknowledgements
The work is supported by scientific project 5.FTT/ 03.2019 „Possibilities of using bioprotectors in the production of functional foods“.

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