EXAMINATION OF THE EFFECT OF TYPE AND QUANTITY OF SUGAR ON MAIN SENSORY PARAMETERS OF HOMEMADE OAT-FLAKES BISCUIT

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Short running title: **SENSORY PARAMETERS OF OAT-FLAKES BISCUIT**

Abstract

The fiber intake is an important part of the human diet. The fiber-deficient nutrition may have long-term health problems. Oat (*Avena sativa*) is an excellent source of fiber and it has many health benefits due to its rich vitamin and mineral composition. Oats are used as flour and flakes in the food industry. The oat-flakes can be used in a variety of cakes but it can be also consumed as breakfast cereals or porridge.

The objective of our work was to determine the effect of the sugar content and sugar types on main sensory parameters of oat-flakes biscuit. During the experiments six different types of biscuit were made with the addition of white or brown sugar at three different concentration level. The moisture content, color and the frangibility of the samples were analyzed during the four-day storage period. The sensory evaluation of the biscuit samples was also performed on the first day of storage.

The parameters of the rupture test and color measurement did not show significant changes during the storage but the individual types of biscuits made of different types and quantities of sugar could be well distinguished. Results of sensory evaluation showed significant differences in frangibility, structure and stickiness parameters.

Keywords: Oat-flakes, sugar, rheology, sensory evaluation

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Introduction

The common oat (*Avena sativa*) is species of cereal grain mainly grown for its utilization for human consumption as oatmeal as well as for livestock feed. Oat has always been regarded as a health promoting food without clear knowledge of its specific health related effects. However, today it is known for its effects on satiety and retarded absorption of nutrients as well as a deterrent of various disorders of the gastrointestinal tract. These beneficial effects are chiefly due to the soluble fiber content of oats (Daou and Zhang, 2012). Today oats is among the richest and most economical sources of soluble dietary fiber. The present interest in soluble oat fiber originated from reports that showed that dietary oats can help in lowering cholesterol postprandial blood glucose level as well as modifying immune response and reducing risk of colon cancer (Wood, 1986; Skendi et al., 2003; Lazaridou and Biliaderis, 2007).

In the food industry there are several ways to use the meal of oats. Consuming oats as flakes is perhaps the most popular today. The oatmeal is obtained by extrusion from the whole eye, so it contains all its components. Used for decoration of bakery products, whole or minced, but also suitable for enrichment or densification of dough as oatmeal flour (Szabó, 1982).

The nutritional values of oat genotypes and practicability of food prepare were investigated by researcher of the ÉKI-NAIK. The change of the ß-glycan as dietary fiber was detected during the research. Food product was developed with high oat and high β-glucane content. The developed muffin was healthier with good enjoyment value. (Veisz et al, 2007).

In order to elucidate the effect of sugar composition on the water sorption and softening properties of cookie, three types of sugar composition (sugar alone, sugar-trehalose, and sugar-sorbitol) were employed as an ingredient of cookie, and softening temperature of the cookie samples, adjusted to various water contents, was investigated using thermal rheological analysis (Kawai et al., 2014). The softening temperature decreased linearly with increasing water content of the cookie samples. The results suggest that sugar composition plays an important role in the softening properties of cookie samples.

Experiment was made to find an optimal recipe for biscuits with the addition of pollen, and at the same time to investigate the physical, chemical and health-promoting properties in the obtained products (Krystyjan et al., 2015). Biscuits improved with bee pollen were characterized by higher penetration work and having a darker surface when compared to the control. Applying bee pollen to fortify the biscuits was possible, and even at the stage when the highest amount was applied, this addition enabled the desired results.

The sensory characteristics are one of the most important criteria for shopping our food products, thus they have a great impact on consumers decision. The main purpose of sensory testing is to determine how well the product meets the consumer's expectations. This is an important element in development of the product. The objective of our work was to determine the effect of the sugar content and sugar types on rheological and sensory parameters of oat-flakes biscuit.

Materials and methods

Biscuit samples

During the experiments six different types of biscuit were made with the addition of white or brown sugar at three different amounts (10, 15 and 20dkg). Each group consisted of 15 samples. Two parallel 4-day short-time storage experiments were performed on two consecutive weeks. The storage parameters were as the follows (Table 1.):

Table 1. Storage parameters of oat-flakes biscuits

experiments	temperature	relative humidity
1.	27.0±0.3°C	22.2±2.5%
2.	27.1±0.9°C	27.9±2.5%

Methods

The moisture content of the samples was determined with classical drying method in VENTICELL (MMM Medcenter, München, Germany) drying chamber. The samples were dried at 105°C, 24 hours until constant weight.

The color of the biscuits was also measured every day during the storage by ColorLite sph850 (ColorLite GmbH, Katlenburg-Lindau, Germany) spectrophotometer. Test results were obtained as CIE (Commission Internationale de la Éclargie) L*, a*, b* color properties. The instrument settings were “2° standard observer” and “standard illuminant D65”. Results of each measurement were calculated from the average of three measurements by the ColorLite equipment. The aim was to control the similarity of the groups.

The frangibility of the biscuits was measured by TA.XT.Plus (Stable Micro System, Surrey, UK) precision penetrometer, with P0.5S type, 0.5 col diameter stainless steel ball. Test settings were as follows: pre-test speed at 1 mm/s, test speed at 0.1 mm/s and distance at 6 mm. A 5kg load cell was used and the maximum rupture force (F_{MAX}) and the distance of maximum rupture force (D_{MAX}) were measured. Furthermore, the gradient of the curve up to maximum force (F_{MAX}/D_{MAX}) and the area below the rupture curve, such as work (A) were determined.

During the sensory evaluation aim was to set in order the groups based on the individual sensory parameters. These parameters were as the follows: shape, thickness, color, structure, global smell, frangibility, stickiness, sweet taste intensity, general aspect. The samples were evaluated by 21 non-qualified panelists. Each panelist tested 1-1 sample from the 6 groups (Figure 1.).

Figure 1. Samples from the 6 different recipes

All samples on the unstructured scale had to be placed between the positive and the negative end of the given property based on nine properties. The full length of the scale was 100%, the distance between the beginning of the scale and the sample mark was measured. Finally the samples in a 0-100 point system were scored.

The measured rheological properties values were evaluated by R-Studio Version 1.1.414 (R-Studio, 2018). After leaving the outlier data, a normality test (Shapiro-Wilk Test) was run on results of the samples. ANOVA was used to identify any significant differences between the groups in the case of certain parameters. Where ANOVA indicated TukeyHSD test ($p<0.05$) was used for detecting the significant differences between the groups (Reiczigel et al., 2014). Sensory attributes were predicted based on the results obtained with mechanical tests parameters by the means of PLS regression (Kvalheim, 2009). PLSR models were built based on F_{MAX}, D_{MAX}, F_{MAX}/D_{MAX} and A parameters obtained by TA.XTPlus to predict the average frangibility, structure and stickiness properties determined by the sensory panelists.

Results and discussion

The moisture content increased in the white sugar biscuits and decreased in the brown sugar samples during the 4-days storage period.

Significant change was not found in the color parameters during the storage. However, the higher sugar content samples were darker due to caramelization. This was also confirmed by the decrease in the values of L*, a* and b*.

The frangibility of the biscuit samples were detected during the rupture test. From the determined rheological parameters the gradient (F_{MAX}/D_{MAX}) was the strongest in the function of the storage time (Figure 2). The error bar diagram reveals at 95% confidence interval the average and the standard deviation of the groups at both of experiments. The standard deviation of group with lower sugar quantity was higher.

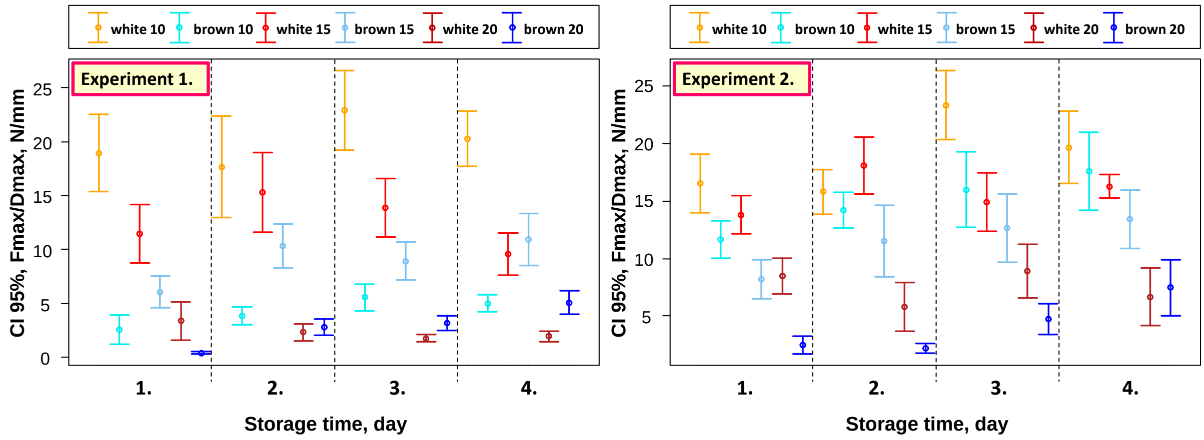

Figure 2. The gradient (F_{MAX}/D_{MAX}) (average and the 95% confidence interval) in the function of the storage time, (experiments from left to right: 1. and 2.)

There was no significant decrease of the value of the gradient observed during the 4-day storage, however decreasing was observed with the increasing of the sugar content at both series. The ANOVA and the TukeyHSD test showed the significant difference among the three different sugar concentration in case of white sugar and brown sugar as well (Table 2/A). The F_{MAX}, D_{MAX} and area (A) showed similar results to the gradient, however the smallest significant difference was found in the D_{MAX} values, but it was also sign according to the TukeyHSD test (Table 2/B). Table 3. shows the TukeyHSD test results of the maximum rupture force (F_{MAX}) and the area (A).

Table 2. TukeyHSD test results of gradient (F_{MAX}/ D_{MAX}) and distance (Dmax) ($p < 0.05$)

A

Fmax/Dmax (exp. 1.)	white 10	brown 10	white 15	brown 15	white 20	brown 20
white 10						
brown 10	+					
white 15	+	+				
brown 15	+	+	+			
white 20	+	-	+	+		
brown 20	+	-	+	+	-	

Fmax/Dmax (exp. 2.)	white 10	brown 10	white 15	brown 15	white 20	brown 20
white 10						
brown 10	+					
white 15	+	-				
brown 15	+	+	+			
white 20	+	+	+	+		
brown 20	+	+	+	+	-	

B

Dmax (exp. 1.)	white 10	brown 10	white 15	brown 15	white 20	brown 20
white 10						
brown 10	-					
white 15	-	-				
brown 15	-	-	-			
white 20	+	+	+	+		
brown 20	+	+	+	+	-	

Dmax (exp. 2.)	white 10	brown 10	white 15	brown 15	white 20	brown 20
white 10						
brown 10	-					
white 15	-	-				
brown 15	+	-	+			
white 20	+	+	+	-		
brown 20	+	+	+	+	+	

Table 3. TukeyHSD test results of maximum rupture force (F_{MAX}) and area (A) ($p < 0.05$)

A

Fmax (exp. 1.)	white 10	brown 10	white 15	brown 15	white 20	brown 20
white 10						
brown 10	+					
white 15	+	+				
brown 15	-	+	-			
white 20	+	+	-	+		
brown 20	-	+	-	-	+	

Fmax - (exp. 2.)	white 10	brown 10	white 15	brown 15	white 20	brown 20
white 10						
brown 10	-					
white 15	+	+				
brown 15	+	+	+			
white 20	-	-	+	+		
brown 20	+	+	+	-	+	

B

Area (exp. 1.)	white 10	brown 10	white 15	brown 15	white 20	brown 20
white 10						
brown 10	-					
white 15	-	-				
brown 15	+	+	+			
white 20	+	+	+	+		
brown 20	+	+	+	+	+	

Area (exp. 2.)	white 10	brown 10	white 15	brown 15	white 20	brown 20
white 10						
brown 10	-					
white 15	-	-				
brown 15	+	+	+			
white 20	+	+	+	+		
brown 20	+	+	+	+	+	

The sensory test was performed by 21 non-qualified panelists. Figure 3. shows the average of the points of each sensory property. The lower point means the more positive properties, which are underlined on the diagram.

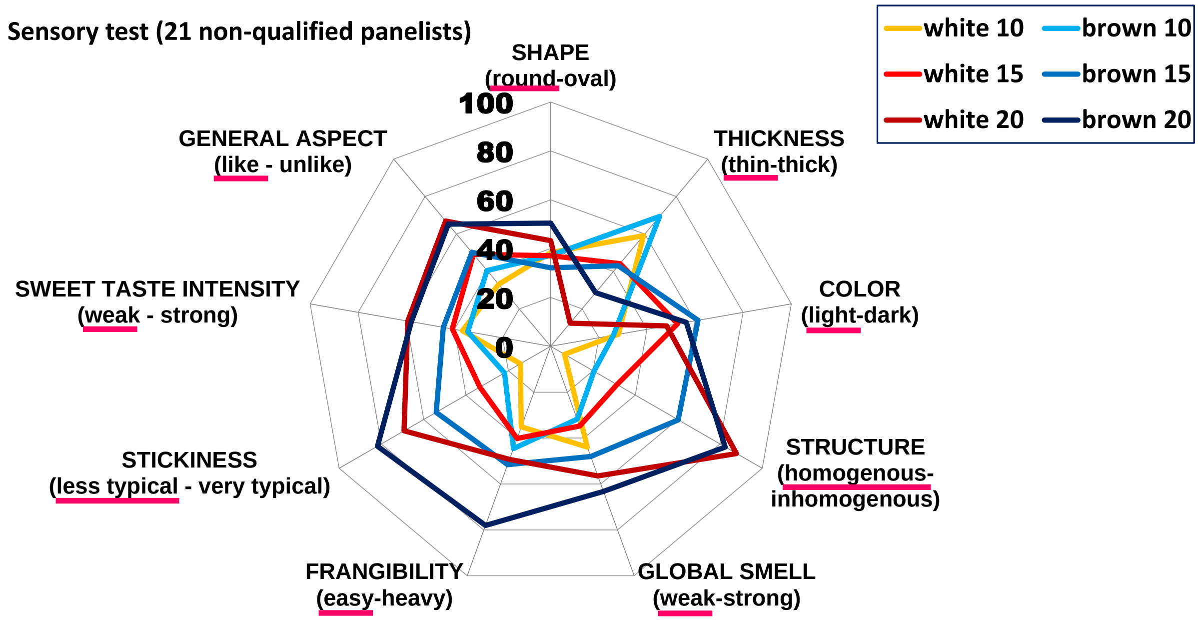

Figure 3. The results of the sensory evaluation based on 9 sensory properties

The frangibility, structure and stickiness properties showed the highest significant difference ($p<0.01$) between the groups based on the judging by points. The groups were separated successfully based on the stickiness and structure properties according to the increasing sugar concentration. The groups did not separate well based on the frangibility; however the original aim of this work was to analyze the frangibility of the biscuits during storage (Table 4). The reason for this was the soft, sticky stock of higher sugar concentration samples.

Table 4. Tukey test results of frangibility, structure and stickiness ($p < 0.05$)

Frangibility

	white 10	brown 10	white 15	brown 15	white 20	brown 20
white 10						
brown 10	-					
white 15	-	-				
brown 15	-	-	-			
white 20	-	-	-	-		
brown 20	+	+	+	+	+	

Structure

	white 10	brown 10	white 15	brown 15	white 20	brown 20
white 10						
brown 10	+					
white 15	+	-				
brown 15	+	+	+			
white 20	+	+	+	+		
brown 20	+	+	+	+	-	

Stickiness

	white 10	brown 10	white 15	brown 15	white 20	brown 20
white 10						
brown 10	-					
white 15	-	-				
brown 15	+	+	+			
white 20	+	+	+	-		
brown 20	+	+	+	+	-	

Results of the first day samples of both of experiments were applied to the PLS regression (Table 5.). The frangibility, structure and stickiness properties of biscuits made of brown sugar are estimated based on the F_{MAX}, D_{MAX}, F_{MAX}/D_{MAX} and A rheological parameters.

Table 5. PLS calibration and cross-validation (leave one out (LOO)) to predict the sensory properties of oat-flakes biscuits based on the results of the maximum rupture force, distance of maximum rupture force, gradient (ratio of maximum rupture force and distance), and area

Experiment	Sensory property	LV (number)	calibration		cross validation	
			R^2	RMSEC*	R^2	RMSEP**
1.	Frangibility [A]	9	0.6798	17.94	0.3631	20.53
	Structure [A]	9	0.8030	5.695	0.7166	6.822
	Stickiness [A]	9	0.7441	12.43	0.6611	14.29
2.	Frangibility [A]	10	0.5977	19.53	0.4782	22.23
	Structure [A]	10	0.8890	4.537	0.830	5.606
	Stickiness [A]	10	0.6918	13.61	0.5963	15.56
1.	Frangibility [B]	9	0.8388	14.25	0.7192	18.75
	Structure [B]	9	0.8395	2.427	0.7235	3.177
	Stickiness [B]	9	0.8396	9.554	0.7231	12.52
2.	Frangibility [B]	7	0.6506	20.49	0.4833	24.87
	Structure [B]	7	0.6566	3.457	0.4880	4.212
	Stickiness [B]	7	0.6556	13.64	0.4874	16.60
1.	Frangibility [C]	9	0.9616	5.053	0.9000	8.126
	Structure [C]	9	0.9713	2.322	0.9271	3.692
	Stickiness [C]	9	0.9636	4.600	0.9064	7.346
2.	Frangibility [C]	10	0.8734	9.143	0.7529	12.72
	Structure [C]	10	0.9224	3.913	0.8247	5.849
	Stickiness [C]	10	0.8960	7.798	0.7846	11.17

* root mean square error of calibration; ** root mean square error of prediction. [A] estimation based on maximum rupture force, distance of maximum rupture force, gradient, area at white and brown sugar groups [B] estimation based on maximum rupture force, distance of maximum rupture force, gradient, area at white sugar groups. [C] estimation based on maximum rupture force, distance of maximum rupture force, gradient, area at brown sugar groups. LV: latent variable

The Figure 4. shows the results of the prediction of the frangibility, structure and stickiness sensory properties of based on the data of experiment 1. The Figures contain the parameters of calibration and leave one out (LOO) cross - validation.

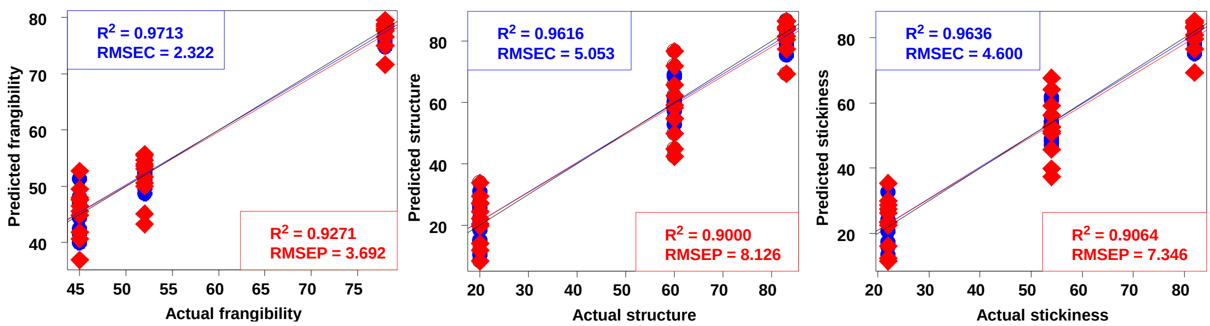

Figure 4. PLSR Results of the prediction of the frangibility, structure and stickiness sensory properties of experiment 1. based on maximum rupture force, distance of maximum rupture force, gradient and area

Close and acceptable correlation was found between the estimated and measured parameters based on the correlation of the cross – validation at frangibility, structure and stickiness. The structure showed the closest correlation (R^2 = 0.9271 and R^2 = 0.8247) and the frangibility showed the weakest correlation (R^2 = 0.9000 and R^2 = 0.7529).

Conclusion

The objective of our work was to determine the effect of the sugar content and sugar types on rheological and sensory properties of oat-flakes biscuit. The determined parameters of rheological measurement not revealed large-scale change during the short-time storage, however significant differences were found in the rheological parameters in case of the white and brown sugar. The best descriptive parameter was the gradient of the curve until the maximum rupture force (F_{MAX}/D_{MAX}). The F_{MAX}, D_{MAX}, F_{MAX}/D_{MAX} and A parameters are able to distinguish the structure of biscuits depending on the different quantities of sugar and sugar types. Based on the results of the sensory evaluation it can be stated that among the nine sensory aspects the rheological properties show a significant difference in the different recipes. These sensory properties were predicted based on the F_{MAX}, D_{MAX}, F_{MAX}/D_{MAX} and A. The structure, frangibility and the stickiness sensory properties of biscuits with brown sugar content are estimated with close and acceptable correlation based on the rheological parameters at two parallel experiments.

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