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Effect of β-glucan on the Physicochemical and Sensory Characteristics of Cookies for Patients with Type 2 Diabetes during Shelf Life.

Nataliya Zhilinskaya*, Varuzhan Sarkisyan, Valentina Vorobyeva, Irina Vorobyeva, Alla Kochetkova, and Elena Smirnova.

Federal State Budgetary Scientific Institution "Federal Research Centre of Nutrition, Biotechnology and Food Safety", 2/14 Ustiinskiy proezd, Moscow 109240, Russian Federation.

ABSTRACT

The present study explores the possibility of using barley flour, oat flour, and buckwheat flour as sources of β-glucan in cookies for patients with type 2 diabetes. It is widely known that β-glucans reduce the serum cholesterol levels and the blood glucose concentration, but their effect on the physicochemical and sensory characteristics of food products are not well described. The objective of this study was to develop cookies with modification of the carbohydrate profile by β-glucans and to determine their physicochemical and sensory characteristics during shelf life. Physicochemical characteristics (moisture content, fat content, peroxide value, water activity, β-glucan content), sensory characteristics and consumer acceptability were evaluated in developed cookies. Results of this research have shown that inclusion of β-glucans has no effect on total liking score and quality indicators of the developed cookies during shelf life.

Keywords: cookies for patient with type 2 diabetes, β-glucans, physicochemical characteristics, sensory characteristics, consumer acceptability, Face Reader

***Corresponding author**

INTRODUCTION

ß-glucans are physiologically active substance and have a positive effect on several physiological functions in human body. A large number of studies have demonstrated the efficacy of β-glucans in the treatment and prevention of some diseases such as diabetes, coronary heart disease, colorectal cancer [1]. Based on these studies European Commission had been established a nutrient reference value for oat and barley β-glucans: 3 g per day of β-glucans to lower the blood LDL-cholesterol concentration, and 4 g of β-glucans for each 30 g of carbohydrates to lower the blood glucose concentration after the meal [2].

The most popular food products-sources of β-glucans are baked foods, such as bread, muffins, cakes, and cookies. Oat flour and barley flour are the main raw materials in the production of baked products enriched by β-glucans [3]. The clinical study has shown that intake of cookies consisting of a barley flour, oat flour, and buckwheat flour yield to the positive effects on postprandial glycemia of patients with type 2 diabetes [4].

The addition of β-glucans into cookies not only provides the positive effects on the organism, but also affects on the technological and quality attributes, including water-binding capacity, emulsion stabilizing capacity, thickening ability, texture, and appearance [5]. Besides influence on the physicochemical characteristics, β-glucans can improve or deteriorate the sensory properties of products. For example, substitution of fine wheat flour by oat flour in bread results to the improvement of the quality in terms of crust color, bread softness, and taste. However, only low levels of β-glucans in cookies allow to kept competitive physicochemical and sensory properties of products [6].

Thus, the development of food fortified by β-glucans remains highly challenging task as consumers are not willing to accept greater health benefits at the expense of deteriorations in sensory characteristics of food products [7].

That is why a large role in our study played the sensory analysis. In this study, we have used a combination of profile analysis and sensory evaluation methods of consumer preferences, for a complete assessment of product sensory characteristics because only one type of these analyses may not provide a clear understanding of the sensory characteristics of the product [8]. Besides that, we have used Noldus Face Reader 6 (Noldus International Technology, Wageningen, The Netherlands), which could measure the facial reaction of consumers. Currently, Face Reader is used mainly for research in the fields of psychology, education, market and consumer behavior research, and a few works have been published about the actual tasting of foods using Face Reader technology such as tasting of orange juice [9]. For this reason, it was interesting to evaluate cookies using the Face Reader technology.

In addition, physicochemical and sensory characteristics during shelf life might be affected by the choice of packaging material. As cookies refer to a category of products, subjected to the influence of oxygen and water vapor. In this study, we have used a non-oriented polypropylene (PP) and two-layer polypropylene film, one layer of which is biaxially oriented polypropylene film and other layer is opalescent biaxially oriented polypropylene film (BOPP/pearlized BOPP). The choice of these films is due to the high mechanical strength, low gas and water vapor permeability, as well as widespread in the Russian market of packaging materials [10].

The aim of this study was to investigate whether the addition of β-glucans via barley flour, oat flour and buckwheat flour to cookies could affect physicochemical and sensory properties and consumer liking during shelf life.

MATERIALS AND METHODS

Cookies preparation

Experimental cookies were produced in the Laboratory of alimentary correction of disorders of the metabolome of the Federal Research Centre of Nutrition and Biotechnology. Table 1 shows the formulation and ingredients used for experimental cookies.

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Table 1: Cookies formulation used in the study

Ingredients	Amount (g/100 g)	Source or manufacturer
Oat flour	24.32	Hlebzernoproduct, Russia
Barley flour	24.21	Hlebzernoproduct, Russia
Buckwheat flour	13.74	Hlebzernoproduct, Russia
Oat bran (contains 27-29% ß-glucan)	0.87	DSM Nutrition Products Ltd, Switzerland
Maltitol	20.17	Shandong Lujian Biological Technology Co., Ltd, China
Butter	18.54	Krasagroprom, Russia
Egg powder	2.18	RUSPRODUCT, Russia
Dry whole milk	2.68	RUSPRODUCT, Russia
Baking powder	1.64	Dr. Oetker, Russia
Vanillin	0.22	Aronap, Russia
Ginger	0.22	Hlebzernoproduct, Russia
Cinnamon	0.22	Arnop, Russia
Steviol glycosides	0.04	Xinghua GL. Stevia Co., Ltd, China
Water	29.00	-

The flowchart of procedures used for the production of the experimental cookies is shown in Figure 1.

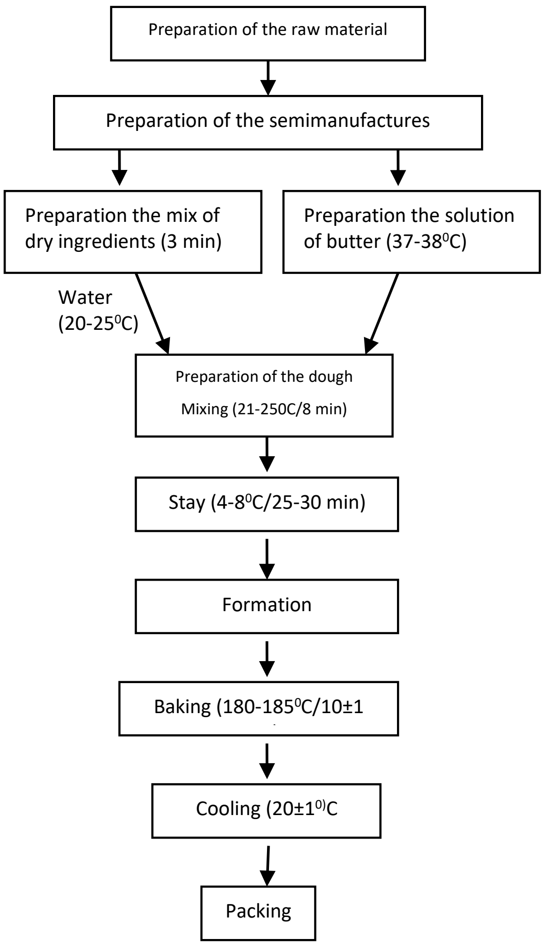

Figure 1: Flowchart for preparation of cookies with the modification of the carbohydrate profile

Oat flour, barley flour, buckwheat flour, oat bran, maltitol, egg powder, dry whole milk, baking powder, vanillin, ginger, cinnamon, steviol glycosides were mixed in a mixer (Model: MUM-XL 40G; Bosch GR, Germany) for 3 min at 130 rpm. Then melted butter (37-38°C) was added to the dry mixture and mixed once more for 3 min at 130 rpm. Following the adding of water (20-25°C) the dough was mixed for 5 min at 145 rpm. Mixed dough was transferred into the glass bowls, covered with three layers of plastic wrap to prevent moisture loss, and kept in a refrigerator for 25-30 min. After that 12 portions (~6.5 g) of dough were placed on a baking sheet and baked in a preheated electric oven (Model: EO 32352; DeLonghi Co., Italy) at 180-185°C for 10±1 min. Baked cookies were cooled to ~20°C before storing experimental cookies. Cookies were packed in PP and BOPP/pearlized BOPP and stored at 18±5°C for 6 months. Three replicates of experimental cookies were prepared for instrumental and sensory analyses at 4 control points: the 1st point was 0 month, 2nd point - 2 months, the 3rd point - 4 months, and the 4th point - 6 months.

Microbiological evaluation

Before carrying out a physicochemical and sensory evaluation, a microbiological control of cookies samples was done. The total counts of mesophilic aerobic and facultative anaerobic microorganisms, total coliforms as well as molds and yeasts were determined [11]. The populations of mesophilic aerobic and facultative anaerobic microorganisms in all cookie samples at 4 control points were less than $0.9{\times}10^3$ of colony forming units per gram of product (CFU g−1). In the case of molds and yeasts, they were less than 10.0 CFU g−1 at all control points. Total coliforms were not detected in all cookies samples. Thus, the samples of experimental cookies were admitted for a further sensory evaluation.

Physicochemical evaluation

Moisture content. Moisture content was determined by drying samples of experimental cookies (~1 g) in moisture analyzer (Model: MJ33; Mettler Toledo, Switzerland) at 130 ±1°C to constant weight.

ß-glucan content. The content of β-glucans of experimental cookies was determined by an enzymatic-gravimetric method using the mixed linkage beta-glucan assay kit (Megazyme, Ireland) [12].

Fat content. Fat content was estimated by extracting a weighed sample of experimental cookies (~5 g) with petroleum ether (boiling point 100°C) in a Soxhlet apparatus for 5 h. The extract containing fat and petroleum ether was evaporated over a steam bath and dried in an oven at 100°C, weighed and then the amount of fat was calculated [13].

Peroxide value. Peroxide value of pre-extracted with petroleum ether samples of experimental cookies was determined in accordance with ISO guidelines [14].

Water activity. Water activity (aw) of experimental cookies was measured by the chilled-mirror method with a water activity meter (Model: AquaLab, 4TE; Decagon Devices Inc., USA). It was calibrated with a lithium chloride standard solution (8.57 molal, at 25°C, Aw=0.500, Decagon Devices). The samples were crushed and placed in the sample cup and then inserted into the chamber.

Sensory evaluation

Samples that were included in this sensory study are as follows: experimental cookies and commercially available oatmeal cookies on fructose (Petrodiet, Russia) as the most similar product.

Recruitment and selection of judges. Sixty candidates (30 men and 30 women) were recruited based on their interests, availability, health, habits, and food preferences. Pre-selected candidates were examined to identify their threshold in basic tastes, odor identification, and discriminating capabilities of color, odor, texture, sweetness, and acidity stimuli through triangular tests. The final trained panel was made up of 7 judges: 2 men and 5 women (age 18-40 years) [15].

Descriptors and judge training. Subjects were trained in two sessions, each lasting 3-4 h, over a period of 2 days prior to the sensory profiling. Two cookies samples were prepared with the goal to reach an agreement as to what terms will be used to describe the fully sensory characteristics of the different judges.

Based on the results obtained during the 2 days the final set of attributes was developed. The final list of the organoleptic attributes with the definition is presented in Table 3 [16].

Trained panel evaluation. After training completion, the panel evaluated two cookies (experimental and commercial samples). The evaluation was performed in individual booths with artificial light and controlled temperature (25±2°C) in accordance with ISO guidelines [17]. Assessors were asked not to smoke, eat and drink anything, except water, at least 1 h before the tasting session. Each judge received samples with a code number consisting of three random digits. The intensity of each attribute was rated using ten-point scale (1=absence of the sensation and 10=maximum intensity). Quantification was done by measuring the marks made by the judges. The judges were instructed to drink water (22±1°C) after each sample to clean their palates. The descriptive analysis of cookies was replicated three times with a fresh batch of cookies each time.

Consumer evaluation. Overall acceptability was evaluated by 50 consumers (32 female, 18 male, 18 to 45 years old, naïve concerning the evaluation procedure) that were recruited among the personnel of the Federal Research Centre of Nutrition and Biotechnology. Panelists received two samples per session in random order. The consumers were not informed that they were video-recoded and their unintentional, automatic facial reactions during and after tasting different samples were analyzed with Face Reader 6. The participants were asked to taste presented samples, then take 20 seconds to reflect on the taste impressions and visualize the taste experience of the sample with a facial expression, representing their liking of the sample. Afterwards, they scored samples using a 7 point hedonic scale, anchored at both ends and in the middle with the expressions described next: to the left side: “I dislike it a lot”, in the middle: “I am indifferent”, and to the right side: “I like it”. After the experiment, participants were asked to give written informed consent regarding the use of their video recordings and collected questionnaire data for further analysis. Informed consent was obtained from all consumers. The sections of the recorded videos for the analysis were selected after the tasting (exactly when the participant took the sample from their lips, the hands do not cover parts of the participant’s face) and lasted until the participant started to score the samples [18] Before the experiment, the participants were asked to give a written informed consent regarding the use of collected data for further analysis. The informed consent was obtained from all consumers.

Statistical analysis

The data of each session during consumers training or sensory evaluation were analyzed through an analysis of variance with a completely random design with a factorial arrangement. The main factors were judges/consumers and samples of cookies. Data distributions were not normal that is why non-parametric correlation methods were used, such as Kendall's correlation (τ), Mann-Whitney U-test. The correlation between sensory attributes and the total liking score of the samples was evaluated with Kendall's correlation coefficient considering the following criteria (r): low correlation from 0.1 to 0.3, medium from 0.3 to 0.5, and high correlation from 0.5 to 1.0 [19].

The analyses were done with a 95% degree of confidence, using Statsoft STATISTICA software.

Table 2: Physicochemical characteristics of experimental samples of cookies

Parameter, value	1st point	2nd point		3rd point		4th point	
		PP	BOPP/pearl BOPP	PP	BOPP/pearl BOPP	PP	BOPP/pearl BOPP
Moisture content, %	6.2±0.1	6.2±0.1	6.6±0.1	6.6±0.1	6.7±0.1	6.9±0.1	6.9±0.1
Fat content, %	17.0±0.1						
Peroxide value, mmol active oxygen/kg	0.5±0.1	0.7±0.1	0.6±0.1	1.3±0.1	1.0±0.1	2.0±0.2	1.8±0.2

a_w, -	0.4650	0.4466	0.5075	0.4317	0.4880	0.4945	0.5153
ß-glucan content	1.8±0.1						

Table 3: List of the sensory descriptors of cookies with their relevant definitions

Attribute(s)	Category	Definition
Sweet	Taste	The basic taste produced by aqueous solutions of various substances such as sucrose
Acidulous	Taste	Describes a product whose taste is alightly acid
Bitter	Taste Flavour	The basic taste produced by dilute aqueous solutions of various substances such as quinine and caffeine
Milk flavour	Flavour	The complex sensation, associated with milk and milk products
Spice flavour	Flavour	The complex sensation, associated with cinnamon, vanilla and other
Off-flavour	Flavour	Atypical flavour often associated with deterioration or transformation of the product
Luminance	Appearance	Degree of lightness or darkness of a colour compared with a neutral grey in a scale ranging from absolute black to absolute white
Shiny	Appearance	The attribute of a glossy surface showing bright reflection
Transparent	Appearance	Describes an object allowing light to pass and distinct images to appear
Correct form	Appearance	The attribute, characterized the form of product
Hardness	Texture	Mechanical textural attribute relating to the force required to achieve a given deformation or penetration of a product
Moisture	Texture	Surface textural attribute which describes the perception of water absorbed by or released from a product
Fracturability	Texture	Mechanical textural attribute related to coheseveness and to the force necessary to break a product into crumbs or pieces
Homogeneity	Texture	Determines by the sense of homogeneity of texture

RESULTS AND DISCUSSIONS

Physicochemical characteristics of experimental cookies during shelf life are shown in Table 2. As it can be seen from the Table 2, the only characteristic that is influenced by storage time is the peroxide value. It is shown that samples, stored in BOPP/pearlized BOPP package have lower peroxide value at the end of the shelf-life. This result might be explained by better protecting properties of BOPP/pearlized BOPP cover against atmospheric moisture migration to the product expressed in the lower humidity and water activity of this samples during shelf-life.

The results from the sensory profiling of the commercial and experimental cookies are presented in Figure 2.

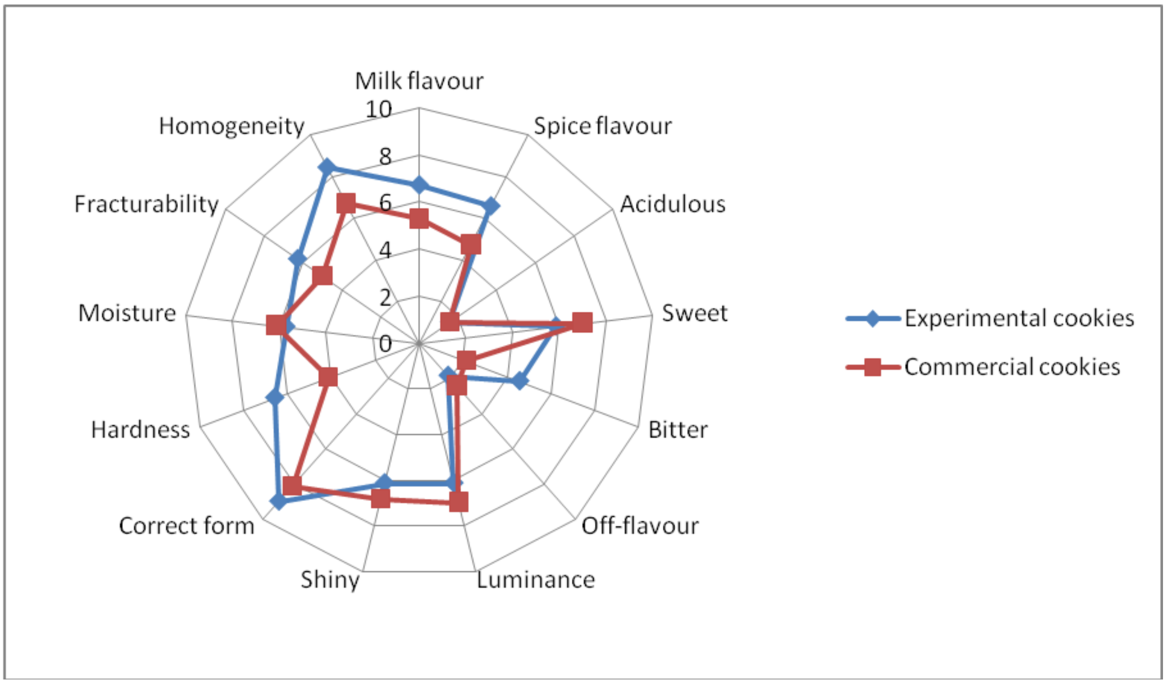

Figure 2: Sensory profile of the samples of cookies [n (panelist) = 7]

As it can be seen from Figure 2, no significant differences between cookies for any attributes were found [20]. An interesting pattern was revealed when analyzing the sensory data with respect to bitter taste. This attribute in experimental cookies is more intense than in the commercial sample, due to a higher amount of raw materials with the content β-glucans. Some studies showed that the introduction of β-glucans sources into the product has a negative effect on the sensory characteristics such as a bitter aftertaste and reduced sweetness [5].

The results from the consumer liking of commercial and experimental cookies are presented in Figure 3.

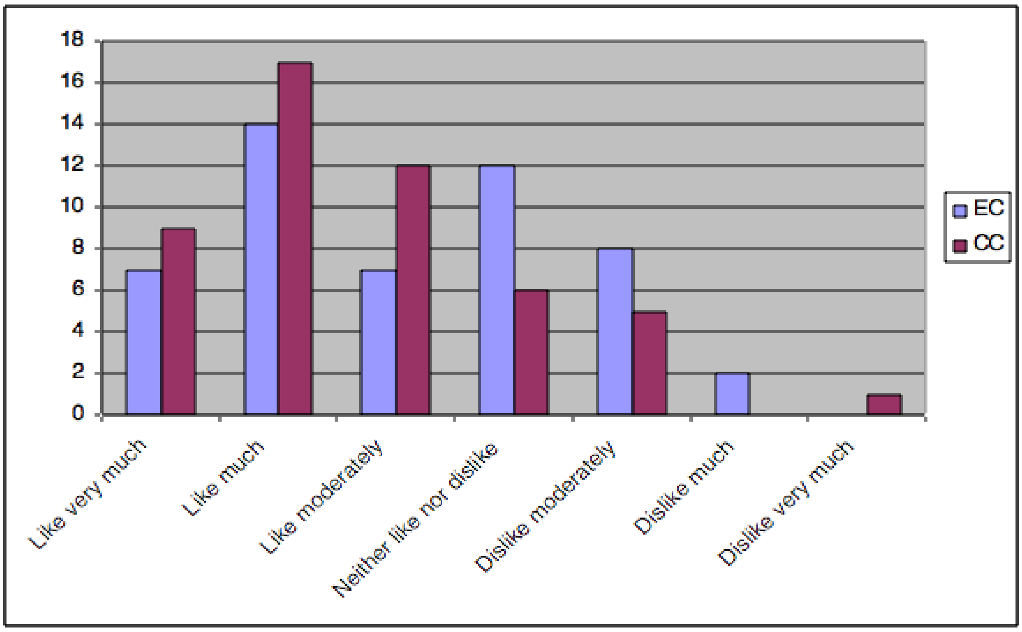

Figure 3: Liking of commercial cookies (CC) and experimental cookies (EC) evaluated by consumer (n=50)

As it can be seen from Figure 3, the sample of the experimental marmalade had slightly lower total liking score, which might be associated with a presence of bitter taste, off-flavor and texture characteristics of this sample.

Analysis of the consumer responses, using software Face Reader 6.1 showed the negative emotions (disgust) in the process of tasting both the experimental and the commercial samples (Figure 4). Slightly higher negative emotions were mentioned for the experimental sample. This study showed that measuring facial expressions using Face Reader is a sufficiently accurate method and its results are comparable to consumer hedonic testing.

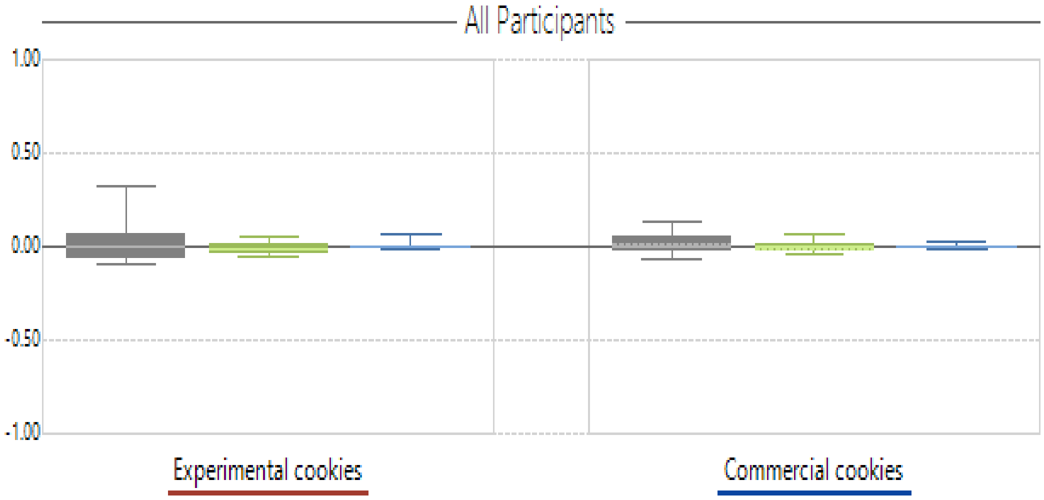

Figure 4: Distribution of the emotional atmosphere of consumers in the process of cookies tasting (grey color – neutral, green color – happy, blue color – disgust)

The results showed that the addition of source β-glucans to cookies affected cookies sensory characteristics. Experimental cookies were generally similar to commercial cookies. But, it should be noted that the consumer data obtained in this study only reflect a small cohort of consumers that usually takes commercial cookies, with high sugar content and do not pose health benefits.

The results from the sensory profiling of experimental cookies packed in PP and BOPP/pearlized BOPP during shelf life are presented in Figure 5 and Figure 6, respectively.

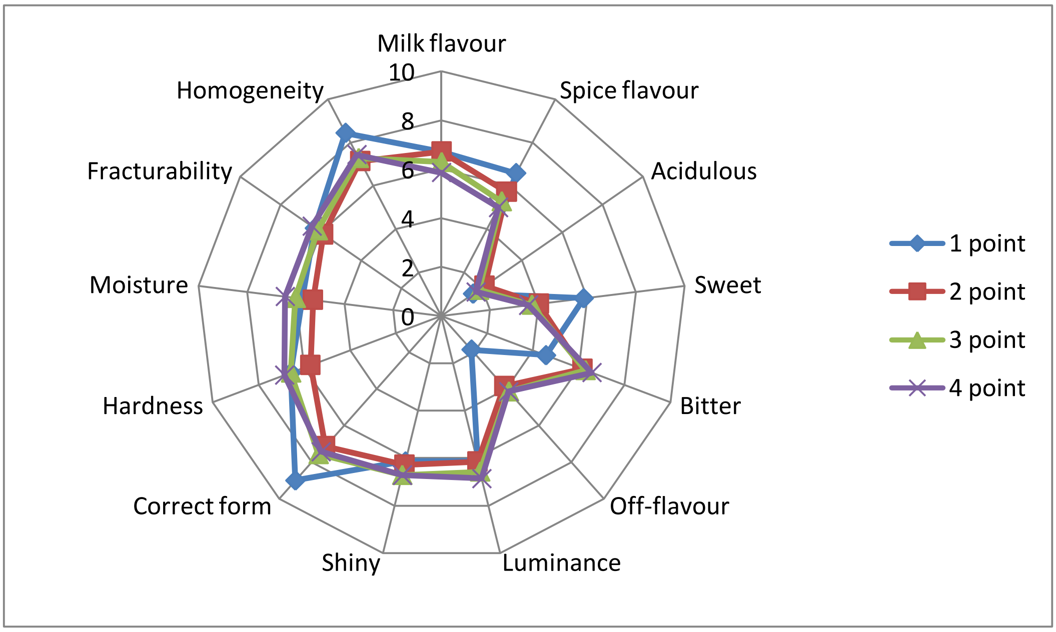

Figure 5: Sensory profile of the samples of cookies packed in PP [n (panelist) = 7]

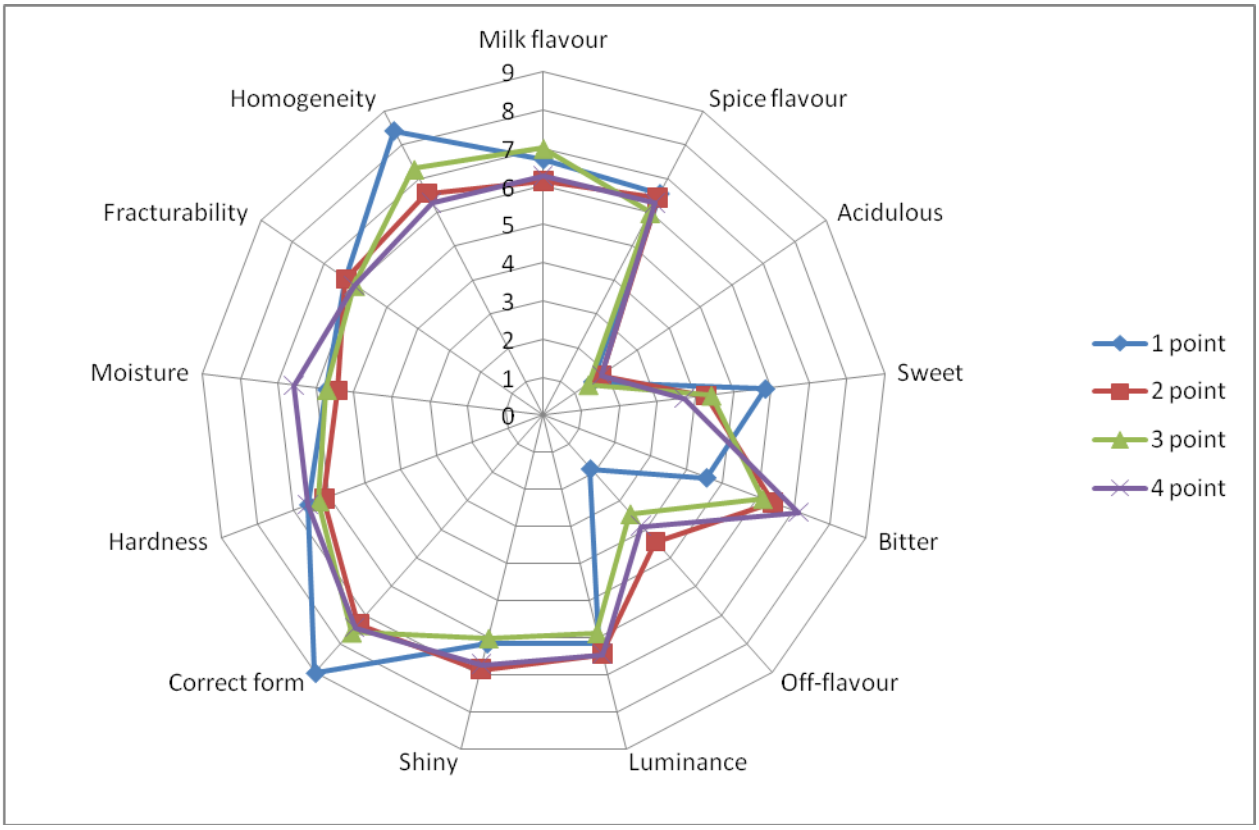

Figure 6: Sensory profile of the samples of cookies packed in BOPP/pearlized BOPP [n (panelist) = 7]

As can be seen, no significant differences between cookies packed in PP and cookies packed in BOPP/pearlized BOPP with regard to the appearance of the attributes were found. Hardness, bitter taste and off-flavor were higher at the 1st point for both samples. During storage packed cookies received the lower scores in these attributes. No significant differences in storage were found for other attributes.

Thus it is shown that all sensory attributes, affected by the addition of the ß-glucans are significantly mitigated during the storage period.

CONCLUSIONS

Information obtained in the study can be a good tool in enhancing the development of a healthy alternative to traditional cookies and therefore new data can be of practical importance for R&D process in the confectionary industry. This unique combination of objectively evaluated sensory properties and subjective consumer liking shown that the addition of β-glucans source is a promising approach to improve the health benefits of cookies while maintaining consumer liking.

Consuming 4 cookies per day (165 g) will provide the consumer with 3 g of β-glucans which the recommended by the European Food Safety Authority level to normalize cholesterol level in blood. Although experimental cookies have almost the same energy value as traditional cookies, the presence of β-glucans makes them a healthier option for many consumers with type 2 diabetes.

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