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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Sensory and textural evaluation of gluten-free biscuits containing buckwheat flour

Tuğba Öksüz^{1*} and Barçın Karakaş²

Abstract: Five different formulations containing buckwheat (*Fagopyrum esculentum*) flour were used in this study to produce biscuit samples which were then analyzed for proximate composition, textural and sensory properties. The different formulations based on incorporation of egg white, carob syrup, and purified starches into the dough formulation yielded final products with different nutritional, sensory, and textural properties. Use of carob syrup to replace table sugar resulted in biscuits with higher outer appearance scores and significantly harder texture. Purified starch substitution on the other hand resulted in high fracturability values. They also had lower protein and higher energy contents. Egg white substitution was aimed at increasing cohesion in the biscuit dough, however, the dough texture of the plain formulation was also acceptable and very subtle differences in biscuit quality were observed with this alteration in the basic formula.

Subjects: Food Additives & Ingredients; Food Science & Technology; Substitutes - Food Chemistry

Keywords: buckwheat; biscuit; texture; starch; grape syrup

1. Introduction

Buckwheat (*Fagopyrum esculentum*) is a pseudocereal plant which originated in China which has a high adaptability for adverse environments and is a traditional crop cultivated in many parts of the world including Asia, Central and Eastern Europe (Wijngaard & Arendt, 2006). It has recently been introduced for cultivation in Turkey as well (Gulpinar et al., 2012). Buckwheat is utilized as a bakery



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Tuğba Öksüz, MSc, is currently doing her PhD study at Istanbul Technical University. She took part in the present study during her Bachelor study term at Akdeniz University, supported with an undergraduate level project fund obtained from TUBITAK.

PUBLIC INTEREST STATEMENT

This study, on a limited scale attempts to characterize the effect of different formulation strategies on the nutritional profile and quality characteristics of gluten-free biscuits. To this end, the researchers have used variations of a base formula by substituting some ingredients in the base mixture with starch, egg white, and carob syrup. The different formulations resulting dough formulations yielded final products with different nutritional, sensory, and textural properties. Buckwheat is a nutritious food source for consumers who have to pertain to a gluten-free diet. On the other hand, these foods can be consumed and appreciated by healthy individuals as well. This study may be a useful reference for researchers in the field as well as for individuals that take part in food preparation and wish to develop novel gluten-free biscuit recipes.

and pasta ingredient in the production of not only gluten-free products suitable for consumption by Celiac disease patients but also as an alternative nutritive food source for the general population. There are gluten-free products in the market, however, there are also concerns regarding their nutritive value, cost and the variety available. In the last decades, the food industry has focused on functional foods; driven by the consumer demand for natural foods that suit their contemporary lifestyle. Buckwheat contains many nutraceutical compounds and has great potential for increased applications in the design of functional foods (Krkošková & Mrazova, 2005; Li & Zhang, 2001). Enrichment of commonly consumed cereal-based foods with buckwheat is the objective of recent studies (Bilgiçli, 2009; Levent & Bilgiçli, 2011).

Granulated sugar or corn syrups are other ingredients used as natural sweeteners in biscuit and cookie recipes. Containing a high amount of (roughly 60%) total sugars, carob syrup, also named carob molasses or pekmez, can be used as an alternative replacement for the sugar used. Approximately 28–30% of Celiac patients have been reported to suffer from protein, calorie, minerals, vitamins, and dietary fiber deficiency (Giménez-Bastida, Piskula, & Zieliński, 2015). Carob syrup when used as an ingredient in biscuit production can boost the mineral content as well as improve the taste. Incorporation of carob syrup into bakery formulations provides added benefits of enriched mineral content as well as other elements of importance for the conservation of health (Özcan, Arslan, & Gökçalık, 2007).

Although the application of pseudocereal flours as gluten-free ingredients is increasing, the commercial production of pseudocereal-containing gluten-free products is limited (Alvarez-Jubete, Arendt, & Gallagher, 2010). There is demand, especially from local medium scale processors, for formulations that will accommodate consumer acceptability of the products. The objective of this study is the evaluation of different buckwheat biscuit dough formulations in terms of the final proximate composition, textural and sensory properties of the products obtained. In order to do so, five formulations were selected among preparatory biscuit cooking trials for producing the test samples.

2. Materials and methods

2.1. Raw materials and biscuit preparation

All ingredients used in biscuit production (corn starch, margarine, granulated sugar, carob syrup, eggs, powder milk, sodium bicarbonate) were purchased from the local market. Buckwheat flour was a kind donation of Yar Bakliyat A.Ş. (Antalya, Turkey). Yar Bakliyat buckwheat flour has been declared to be gluten-free by a report of The Scientific and Technological Research Council of Turkey. Different biscuit dough with designated sample codes DS (main formula), DY (without egg), DK (with carob syrup), DP (with potato starch), and DM (with corn starch) was prepared by mixing the ingredients given in Table 1. Formulations were finalized after several trials. The formulations all include margarine and sodium bicarbonate. In DY, the volume of egg white used was replaced with twice volume of water to achieve equivalent dough consistency. In DK, majority of the sugar and all of the water in the formulation was replaced with equivalent amount of carob syrup containing 60% soluble solids. In DP and DM, half of the buckwheat flour was replaced with potato and corn starch, respectively. Biscuit dough was prepared according to the designated recipes and they were kneaded for 15 min. The dough was left to rest for 30 min at 6°C and rolled out on a Teflon surface to 0.5 cm thickness and cut into 3 × 6 cm rectangular pieces. The shaped biscuit dough was placed on a tray lined with parchment paper and cooked in a conventional temperature controlled oven (Fimak EKF60, Turkey) at 140°C for 40 min. Samples were allowed to cool at ambient temperatures for 30 min prior to conducting the moisture level determinations, proximate, texture, and sensory analyses.

2.2. Chemicals

Sulfuric acid (≥96%), boric acid (H_3BO_3) (≥99.5%), diethyl ether ($(CH_3CH_2)_2O$), n-hexane ($CH_3(CH_2)_4CH_3$), ethyl alcohol (CH_3CH_2OH) were obtained from Merck KGaA (Darmstadt, Germany). Bromocresol green ($C_{21}H_{14}Br_4O_5$), methyl red ($(CH_3)_2NC_6H_4N=NC_6H_4CO_2H$) were purchased from Sigma-Aldrich Chemie GmbH (Steinheim, Germany).

Table 1. Recipes used in the preparation of buckwheat biscuits

Ingredient	Sample code				
	DS	DY	DK	DP	DM
Buckwheat flour (g)	150	150	150	75	75
Corn starch (g)	-	-	-	-	75
Potato starch (g)	-	-	-	75	-
Margarine (g)	45	45	45	45	45
Granulated sugar (g)	75	75	15	75	75
Carob syrup (g)	-	-	90	-	-
Egg white (ml)	3	-	3	3	3
Sodium bicarbonate (g)	3	3	3	3	3
Water (ml)	45	51	-	30	30

2.3. Proximate analyses

The moisture content was determined by drying samples in a heating oven (Binder, Germany). Approximately 10 g sample was weighed into predried and cooled petri dishes after which the samples were dried at 70°C for 12 h. Crude protein was determined by the Kjeldahl method (Gerhardt, Germany) using 6.25 as the conversion factor (ICC, 1980). Method has three steps; digestion, neutralization, and distillation, titration. Digestion aims to breakdown all organic matter by acid and catalyst. Approximately 1 g sample and 20 ml sulfuric acid (96%) were burned gradually 200–420°C. NaOH added burned samples distilled by 25 ml boric acid (4%) and 50 ml water. The distillate was titrated using 0.1 N H₂SO₄ (96%). Ash content was determined by gravimetric measurements following incineration (ICC, 1960). Approximately 3 g sample was weighed into a tared crucible and 1 ml ethanol was added. Samples were burned in muffle furnace (Electromag, M 1813, Turkey) at 900°C until no black stain was left. Lipids content was determined using a Soxhlet apparatus and petroleum ether as the extraction solvent. A 5 g sample was dried in drying oven at 95°C for 2 h. Predried samples were extracted using petroleum ether at a rate of six drops per hour for about 6 h. Samples extracted were dried at 105°C for 1 h and weighed. Crude fiber was determined using an apparatus for digestion (Gerhardt, Germany) according to the ICC (1972) method. A 3 g sample without fat was weighed into the 250-ml flask and 60 ml (900 ml acetic acid 70%, 60 ml concentrated nitric acid, 24 g trichloroacetic acid) added to top. The sample was boiled for 30 min under a condenser apparatus. The sample was then filtered through filter paper (Whatman 41). The filtrate was washed using 380 ml distilled water at 70–80°C until neutral conditions were achieved, and then rinsed with acetone and diethyl ether. Filter paper and its contents were dried at 130°C in a drying oven to constant weight. Total carbohydrates % on dry basis were calculated by subtracting the % values obtained for protein, ash, and lipids from a total value of 100. The gross energy value of the samples was calculated by multiplying energy indexes. Energy indexes for components were 4 kCal/g carbohydrate (non-fiber), 4 kCal/g protein, fat 9 kCal/g fat, and 2 kCal/g fiber.

2.4. Instrumental texture analyses

Biscuit hardness and fracturability (resistance to bending or snapping) was measured using a TA.XTPlus texture analyzer (Stable Micro Systems, Great Britain) equipped with a 3-point bend rig (HDP/3 PB) using a 5 kg load cell and heavy duty platform. The test speed was set to 3.0 mm/s and trigger force was automatic at 50 g. Maximum force was recorded as the hardness value and distance at the point of break was observed as the fracturability value.

2.5. Sensory analyses

Fresh biscuits made using the five different formulations were randomized and coded for evaluation with a quantitative descriptive sensory analysis method (Poste, 1991) for color, appearance, taste, flavor, texture, mouth-feel, and overall acceptability with a panel of 13 trained panelists, of which 6 were male and 7 female. The panelists were asked to evaluate each attribute applying a hedonic

Figure 1. General appearance of biscuits obtained using the different formulations.

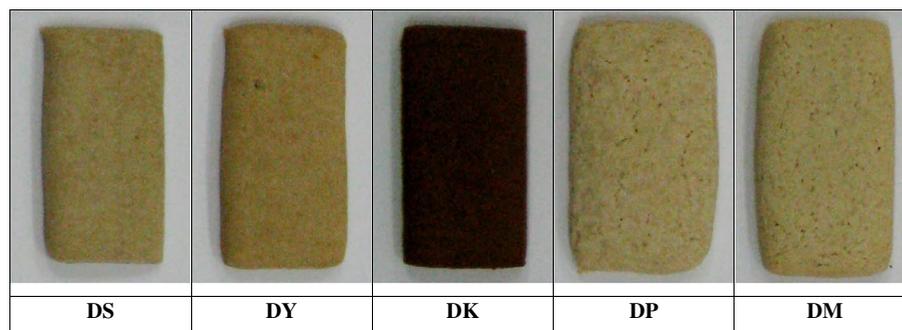


Table 2. Proximate nutritional composition of the five different biscuit formulations

Formula	Dry matter (%)	Protein (%)	Crude fiber (%)	Lipids (%)	Ash (%)	Carbohydrates (%)	Energy value (kCal/100 g)
DS	91.42 ± 0.67 ^c	7.90 ± 0.36 ^a	0.88 ± 0.07 ^a	12.33 ± 0.71 ^a	1.75 ± 0.10 ^b	73.03 ± 1.11 ^b	421.00 ± 6.56 ^{ab}
DY	96.63 ± 0.26 ^a	7.83 ± 0.11 ^a	0.99 ± 0.09 ^a	11.42 ± 0.46 ^a	1.69 ± 0.03 ^b	73.17 ± 1.22 ^b	413.58 ± 2.23 ^b
DK	90.80 ± 0.55 ^c	7.79 ± 0.28 ^a	0.78 ± 0.03 ^a	12.96 ± 0.63 ^a	2.42 ± 0.01 ^a	71.86 ± 0.97 ^b	425.32 ± 2.48 ^{ab}
DP	96.24 ± 0.19 ^a	4.19 ± 0.24 ^b	0.84 ± 0.02 ^a	12.18 ± 0.75 ^a	1.29 ± 0.01 ^c	79.54 ± 0.74 ^a	436.91 ± 3.53 ^a
DM	93.82 ± 0.36 ^b	3.67 ± 0.16 ^b	0.84 ± 0.02 ^a	12.46 ± 0.73 ^a	1.28 ± 0.04 ^c	78.25 ± 0.51 ^a	434.21 ± 3.90 ^a

Note: Values followed by the different letters (a, b and c) are significantly different at $p < 0.05$ level.

scale of 9 points (where 1 = extremely dislike and 9 = extremely like). Samples were coded with three digit numbers and given in randomized order. Panelists evaluated the samples for five descriptors as appearance, overall acceptance, taste, texture, and color.

2.6. Statistical evaluation

Results are expressed as mean value ± standard deviation of triplicate determinations performed on three separately prepared samples. The sensory evaluations are mean values of 13 panelists. All results were analyzed by ANOVA for significant differences ($p \leq 0.05$) using SAS software (SAS, 1996). The comparison of means was carried out by Duncan's Multiple Range Test.

3. Results and discussion

3.1. General appearance and proximate composition

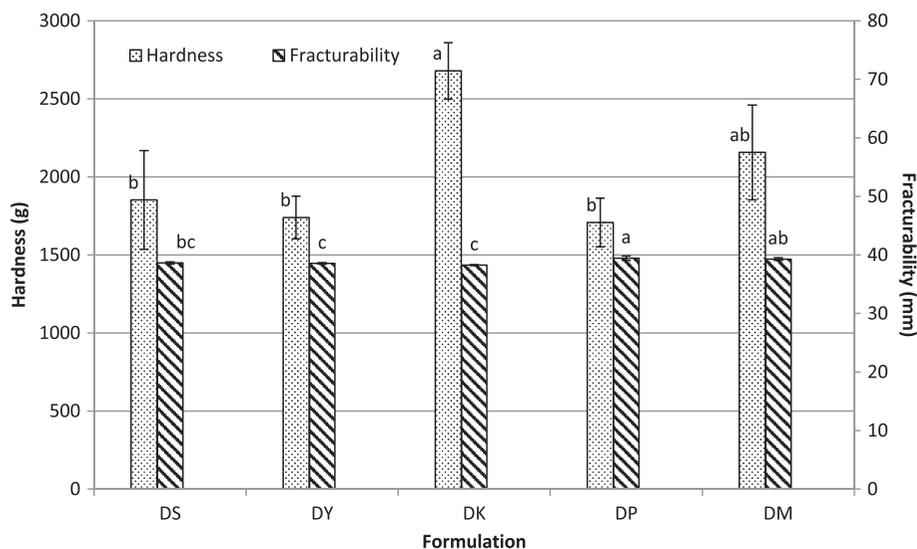
All biscuit formulations resulted in edible products, however, they were very different in terms of appearance (Figure 1) and other properties. General nutritive compositions of the biscuits obtained with the five formulations are presented in Table 2. As fresh, the biscuits contained moisture ranging from about 3–10%. Buckwheat contains approximately 14.1% protein, 3.5% fat, 1.8% ash, 8.3% dietary fiber, and 68.6% carbohydrate (Zhu, 2015). The starch supplemented formulation had significantly lower protein values due to the reduced amount of buckwheat incorporation. Carob syrup has been shown by Aliyazicioglu et al. (2009) to contain approximately 3% mineral matter, much higher than syrups obtained from other botanical sources. It is clear that supplementation of the basic formula with carob syrup resulted in significantly higher mineral matter content.

3.2. Instrumental texture

Biscuit hardness and fracturability values determined are presented in Figure 2. Hardness values were recorded as the peak force applied to break the biscuits on the three-point bend rig. The formulation containing carob syrup (DK) resulted in biscuits with significantly ($p \leq 0.05$) harder texture than the other formulations.

Figure 2. Hardness and fracturability values of the biscuits.

Note: Different lower case letters indicate significant differences ($p \leq 0.05$) within values in a series.

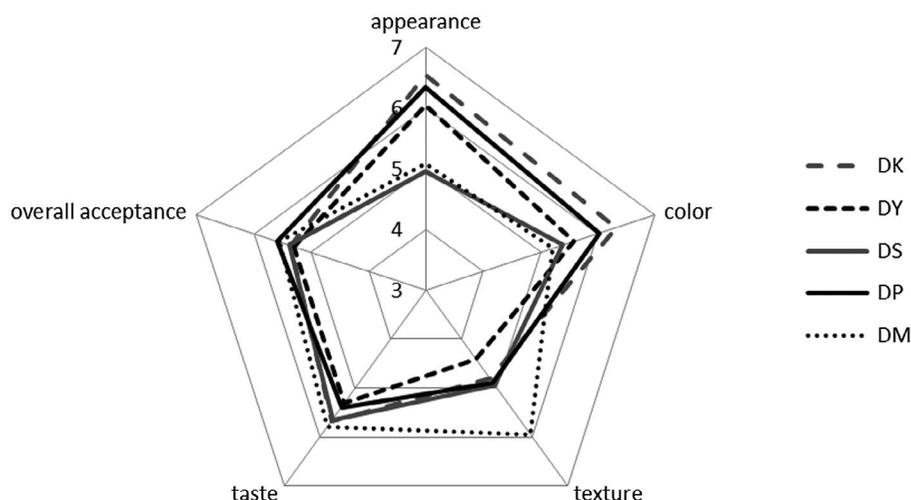


A positive correlation with a coefficient of 0.72 was observed with regard to the hardness values and the moisture content of the biscuits. The harder texture of DK could be attributable to the lower hydration capacity of the water introduced into the mix with syrup. Fracturability value was recorded as the distance taken by the probe until the point of fracture. The fracturability values were higher ($p \leq 0.05$) for formulations containing starch (DM and DP). This could be explained by looser matrix formation in these formulations which contain lower levels of proteins. Although buckwheat does not contain gluten, it did provide a base for dough formation. Although dough rheology was beyond the scope of this study, it was observed that all formulations yielded dough with acceptable quality, easily shaped to the same dimensions. Bejosano and Corke (1999) have indicated that the glutenin and prolamin content of buckwheat seeds comprises approximately 43–45% of the total protein content. So although buckwheat flour does not contain the allergenic gluten fraction, the presence of these protein moieties seems to compensate for the necessary colloidal structure for biscuit dough. The attempt at replacing the water in the formulation with egg white to provide better binding of dough components to compensate for the lack of the gluten proteins had only a slight effect on increasing the hardness value and lowering fracturability.

3.3. Sensory evaluation

All five biscuit formulations were assigned overall acceptability scores above 5 points on a scale of 1–9 points by the panelists. Figure 3 shows the panelists evaluation for overall acceptability as well as those properties for which significantly different scores were assigned for each of the formulations. Judging for individual properties, panelists had a greater preference for the darker color biscuits resulting from the carob syrup formulation (DK). This result is in accordance with results of a study where gums were incorporated into dough mixtures (Kaur, Sandhu, Arora, & Sharma, 2015). The authors reported that acacia gum supplemented buckwheat cookies were darker in color, however, scores for taste for this formulation were lower than the others due to caramelization of sugar. In terms of taste, panelists showed a preference for starch substituted formulations DM and DS. DM was also assigned significantly higher points for texture than the other formulations. The formulations DM and DS had a pale color and porous surface which was not favored by panelists who assigned the lowest outer appearance scores to these. The evaluation for properties of odor, aroma and mouth-feel resulted in mean scores not significantly different between formulations with means ranging from 5.27–5.61, 4.75–5.63, and 5.05–5.69, respectively. It has previously been reported that gluten-free biscuits based on pure starches tend to cause a dry, sandy mouth-feel (Schober, O'Brien, McCarthy, Darnedde, & Arendt, 2003). Substitution of buckwheat flour with starch did not appear to adversely affect mouth-feel property of the biscuits.

Figure 3. Sensory evaluation results for the five biscuit formulations presented for overall appreciation and the four other properties for which the assigned scores had significantly different means.



4. Conclusion

Measurements performed in this study revealed that incorporation of egg white, carob syrup and purified starches in biscuit recipes based on buckwheat flour yielded final products with significantly different nutritional, sensory and textural properties. When designing new products for market exposure, these properties need to be addressed as a whole and the results obtained with the present work will be useful in designing future studies as well as improving buckwheat biscuit quality. Although use of carob syrup to replace table sugar is a good approach for creating variation in the product, resulting in better appearance, the texture does become harder. Purified starch substitution on the other hand results in higher fracturability and products are more fragile and vulnerable to breakage. They also have a lower protein and higher energy content. Egg white substitution was aimed at increasing cohesion in the biscuit dough, however, the dough texture of the plain formulation was also acceptable and very subtle differences in biscuit were observed with this alteration in the basic formula.

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Competing Interests

The authors declare no competing interests.

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