Quality properties of gluten-free boza produced with buckwheat (*Fagopyrum esculentum*) and teff (*Eragrostis tef*) flour

A. Göncü[1,*], Y. Kuzumoğlu[2], I. Çelik[3] and A. Yildirim Vardin[2]

[1]*Department of Food Processing, Çine Vocational School, Aydın Adnan Menderes University, Çine, Aydın, Türkiye*
[2]*Department of Food Engineering, Faculty of Engineering, Aydın Adnan Menderes University, Aydın, Türkiye*
[3]*Department of Food Engineering, Faculty of Engineering, Pamukkale University, Denizli, Türkiye*
**Corresponding author*: ali.goncu@adu.edu.tr

ABSTRACT Boza is a traditional Turkish fermented cereal beverage and typically can be produced from wheat, corn, rice, or millet. This paper aims to significant contribution to the limited availability of gluten-free boza. Gluten-free boza was obtained from buckwheat and teff flour as natural gluten-free ingredients, instead of wheat flour in this study. The results showed that gluten-free boza has more dietary fiber, protein, potassium, magnesium, manganese, phosphorus, and zinc. Substituting gluten-free flour decreased the boza's viscosity, yet this decrease did not affect the sensory analysis results ($p > 0.05$). Also, the results of microbiological analysis of boza demonstrated that BUB had the highest number of LABs of all the gluten-free boza. According to the results of the sensory analysis, panelists rated the gluten-free boza with buckwheat and teff flour highest in terms of flavor and general taste characteristics. It can be concluded that these gluten-free flours can be effectively used in boza production.

KEYWORDS Boza; Celiac; Gluten-free; Buckwheat; Teff

1. Introduction

Boza is derived from the word "Buze," which means millet in Persian. The term boza is commonly used in Türkiye and Balkan states, while the same dish is known as "Buha" or "Merissa" in Iran, Egypt, and other Arab countries (Levent and Algan Cavuldak, 2017). According to the TS 9778 boza standard, boza is defined as "a product prepared by cooking millet, rice, wheat, corn and similar cereals cleaned of foreign matters by adding potable water to one or more of their crushed or flours and subjecting them to alcohol and lactic acid fermentation by adding white sugar with appropriate technique" (Turkish Standard, 2017). Boza is recommended in all age groups with boza microbiota's positive health benefits like strengthening body resistance, regulating the digestive system, etc. (Göncü et al., 2018).

Gluten is the structure known as "wheat protein", which is a combination of the "gliadin" and "glutenin" proteins found naturally in wheat and the main driver of unique viscoelastic property of dough affecting baking quality of bread (Ertop et al., 2016). Celiac disease, a food intolerance in which a permanent flattening of the intestinal mucosa results from gluten consumption, is a lifelong disease that can be seen in children and adults (McAllister et al., 2019). It is most effectively treated by a gluten-free diet. With a better understanding of celiac disease and its effects, research on gluten-free products has significantly increased (Woomer and Adedeji, 2021). In this study, gluten-free buckwheat and teff flours replaced wheat flour in many boza formulations, producing new gluten-free products, and their quality was investigated.

Buckwheat is a broad-leaved, fast-growing annual plant of the *Polygonaceae* family, which is similar in composition to cereals although it is not a grain in terms of botanical characteristics (Öncel and Demir, 2019). Due to the fact that it does not contain gluten, buckwheat causes some problems in bread technology and in the production of bakery products, such as high hardness and low bread volume (Brites et al., 2022; Sedej et al., 2011).

However, buckwheat increases the functional properties and nutritional values of the food it is added to due to its high level of antioxidant activity, phenolic substances, amino acid and fiber components (Bhinder et al., 2019; Hayıt and Gül, 2017; Kumari et al., 2020; Singh et al., 2019; Klepacka and Najda, 2021). According to data from the United States Department of Agriculture (USDA), buckwheat flour contains 6.67 % protein, 3.33 % fat, 10 % dietary fiber, and 73.33 % carbohydrates (USDA, 2019b).

In a study (Tuluk and N., 2019), where different raw materials were used in the production of gluten-free tarhana, buckwheat was found as the richest ingredient in terms of Mg and P among buckwheat, lupine, chickpea, common bean, wheat, corn, and rice flours. In another study, it was shown that various types of buckwheat had a good amount of protein (9.06 to 14.88 %) and contained all essential amino acids, especially high content of leucine, phenylalanine, lysine, and threonine (Bhinder et al., 2020). Also, buckwheat is a rich source of dietary fiber, unsaturated fatty acids, vitamins, minerals, phytosterols and polyphenols (Yaver and Bilgiçli, 2020). Buckwheat flour, which contains approximately 3 times more lysine amino acids than wheat flour, is thus a preferred raw material

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in gluten-free product formulations with low prolamine content (Yıldız and Yalçın, 2013).

Teff, one of the small, round, and tropical gluten-free grains of the *Poaceae* family, can grow in any soil (Kaplan et al., 2016). Teff seeds can be white, cream-colored, or brown in color. While the flour of this seed is primarily used in different bakery products in Ethiopia, its use is becoming more widespread around the world. Since teff is ground and consumed whole, it can be said to have more nutritious properties than options such as wheat, corn, and barley (Kılınççeker and Karaman, 2019). The composition of teff is reported as 8.8 % moisture, 13.3 % protein, 2.4 % fat, 8.0 % fiber, and 73.1 % carbohydrates. High levels of essential amino acids, high mineral content, low glycemic index, high dietary fiber content, higher concentration of bioactive metabolites, longer shelf life and slow staling properties of teff have advantages over widely consumed grains such as sorghum, rice, barley and corn (Gebru et al., 2021). Having a rich amino acid content compared to other gluten-free grains, teff stands out as a good alternative for the development of healthy eating habits in societies nourished with a carbohydrate diet (Sarı and Tiryaki, 2018). Other micronutrients, including minerals and phytochemicals, are also abundantly present in teff (Barretto et al., 2021). In addition, it has been emphasized that teff has significant contributions in preventing diabetes and increasing iron bioavailability (Baye, 2014). As a result of the trend towards healthy food in recent years, teff has started to attract more scholarly attention (İkizoğlu, 2018).

Buckwheat and teff are grown in the climatic conditions in Türkiye and planted areas of them are gradually increasing. The purpose of choosing these two grains in the production of boza in this study, besides the nutritional content mentioned above, is their increase of planted areas in recent years. The use of these grains in food production will contribute to the expansion of their cultivation. In this sense, the main objective of the current study was, to use gluten-free flour obtained from buckwheat and teff grains in the production of a traditional beverage, in order to promote the usage of these valuable grains in the food industry.

2. Methods

2.1 Materials

Raw materials used to produce boza were obtained from local markets in Denizli province (Türkiye) and boza culture (Boza which is sold ready for consumption in the market, has been used as a culture) were obtained from Karakedi Boza Company (Eskişehir, Türkiye). The flours (buckwheat and teff) used were whole flours. The formulations of the gluten-free boza produced in the study are given in Table 1.

Table 1: The formulations of boza.

Raw materials	Boza			
	COB	BUB	TEB	BTB
Rice flour (g)	36	36	36	36
Corn flour (g)	72	72	72	72
Wheat flour (g)	36	-	-	-
Buckwheat flour (g)	-	36	-	18
Teff flour (g)	-	-	36	18
Sugar (g)	230	230	230	230
Water (ml)	1220	1220	1220	1220
Boza culture (g)	36	36	36	36

COB: Control Boza, BUB: Buckwheat Flour Gluten-Free Boza, TEB: Teff Flour Gluten-Free Boza, BTB: Buckwheat Flour and Teff Flour Mix Gluten-Free Boza.

2.2 Preparation of boza

The boza production method of (Çelik et al., 2016) was adapted for this study. Prepared flour mixtures (144 g) were added to 720 mL of water (5 times the weight of the flour) and cooked for 30 minutes with continuous stirring. The obtained viscous mixture was rested for 12 hours and then diluted with 500 mL of water. Sugar (230 g) and boza culture (36 g) were added to the diluted mixture. The prepared mixture was left to incubate at 30 °C for 24 hours. The obtained boza samples were kept in refrigerator conditions (4 °C) until their analysis was completed.

2.3 Physical analysis

The color of the samples (L^*, a^* and b^* values) were measured with a Hunter Lab Scan Colorimeter (HunterLab MiniScan, XE, America) (Anonymus, 1995). Viscosity analyses were carried out with a Brookfield (Model No: SC4-13R) device. Measurements were done at a temperature of 15 °C and with the spindle number SC4-21 (Brookfield Accessories), at 8 different speeds (0.5, 1, 2.5, 5, 10, 20, 50, and 100 rpm). K (consistency coefficient) and n (flow behavior index) values were determined.

2.4 Chemical Analysis

Ash analysis, performed by moisture determination and burning the samples at 550 °C, was performed according to AOAC (1990) standards. In order to determine the degree of acidity, the results were determined by titrating acidity and calculated in terms of lactic acid (Turkish Standard, 2002). pH measurement in Boza was carried out with a digital pH meter (Hanna Instruments HI 8314). The amount of protein was determined by the Kjeldahl method (AACC, 1999) and assumed a nitrogen conversion factor of 6.25. Dietary fiber content was determined using a total dietary fiber measurement kit (Megazyme K-TDFR, Wicklow, Ireland) and the methods in AOAC 991.43 (AOAC, 1995) and AACC 32-07 (AACC, 1995).

Inductively coupled plasma optical emission spectrometry (ICP-OES) was used for mineral determination. The standard element solutions required to draw the calibration curve were prepared from atomic absorption spectrometer standard solutions ("Inorganic Ventures" or "VHG Labs" single-element standards) at 1000 mg/L concentrations of analytical purity.

A 2 % nitric acid solution was used to dilute the standard solutions. At the preliminary stage, the samples were weighed into porcelain crucibles and burned according to AOAC 985.35 (AOAC, 1990), then dissolved in 1 N HNO_3

solution. Operating conditions of the ICP-OES device for analysis were: RF power 1.5 kW, plasma gas (Ar) flow rate 15 L/min, auxiliary gas (Ar) flow rate 0.2 L/min, nebulizer flow rate 0.6 L/min, sample flow rate 1.5 mL/min, lag time 10 seconds, and ambient temperature 24 °C (Boss and Fredeen, 2004).

2.5 Microbiological analysis

Total lactic acid bacteria (LAB) count, yeast, and mold (YM) count, and total mesophilic aerobic bacteria (TMAB) count were calculated for the produced boza. From dilutions prepared from boza samples for microbiological analysis, a De Man Rogosa Sharpe Agar (MRS) medium was used to count total lactic acid bacteria, a Dichloran Rose-Bengal Chloramphenicol Agar (DRBC) medium was used to count yeast and mold, and a Count Plate Agar (PCA) was used for the for total mesophilic aerobic bacteria count. Parallel plating was enabled by spreading samples on each medium. The plates prepared for the total lactic acid bacteria and total mesophilic aerobic bacteria counts were incubated at 30 ºC for 48 hours, while the plates prepared for counting yeast and mold were incubated at 28-30 °C for 5 days. The results were given as log cfu/g by counting the suitable petri plates with breeding (Göncü and Çelik, 2020).

2.6 Sensory analysis

Sensory analyses were carried out with the participation of 40 non-trained panelists at Pamukkale University, Faculty of Engineering, Department of Food Engineering. Panelists were asked to rate boza samples between 1-7 points in terms of color, odor, flavor, consistency, and overall acceptance, using a hedonic scale (Topkaya and Isik, 2019). All the analyzes were done in duplicate.

2.7 Statistical analysis

The "SPSS PASW 22 Statistical Software" program was used to detect changes in substituted raw materials and boza (Arbuckle, 2014). All of the boza batches were produced in duplicate and all of the analyzes were carried out in two parallels. In this context, one-way analysis of variance (ANOVA) was applied. The differences in the samples were evaluated at 95 % confidence intervals by a Duncan multiple comparison test.

3. Results

Physical and chemical properties of the flours are given in Table 2. Wheat flour had the highest *L* value (87.95), indicating brightness, while teff flour had the highest values of *a* (4.27) and *b* (9.93), indicating redness and yellowness. In an earlier study producing boza with different raw materials, Çelik et al. (2016) specified the *L* value of wheat flour as 70.90, with a value of −0.08 and a *b* value of 9.87. Similarly, Tomar et al. (2020) stated that while the *L* value of buckwheat flour was 88.19, the *a* value was 4.70, and the *b* value as 4.87.

Teff flour was the richest raw material type in terms of ash (2.0922 %) content. It was determined that teff and buckwheat flours have similar ($p > 0.05$) content in terms of protein; both are richer in protein than wheat flour. In another study, where teff flour was used in the production of gluten-free crackers, it was stated the teff flour contained 2.21 % ash and 11.72 % protein (Rico et al., 2019). According to USDA data, teff flour contains 2.8 % dietary fiber, 13.3 % protein, and 2.37 % ash (USDA, 2019a). Dizlek et al. (2009) reported that buckwheat flour contained 10.0–12.5 % protein and 1.3–2.3 % ash. Haas et al. (2022) reported that the more teff flour ratio increased in gluten-free cakes, the more amounts of ash and protein increased too.

It was also determined that the substituted raw materials contain more dietary fiber than wheat flour. Nespeca et al. (2021) also stated that using teff flour in the production of cocoa cakes increased dietary fiber. The richest raw material type was determined as buckwheat flour in terms of soluble dietary fiber (1.54 %), insoluble dietary fiber (4.55 %), and total dietary fiber (6.09 %) content. Steadman et al. (2001) reported that buckwheat flour had a soluble dietary fiber content of 4.2–4.8 %, insoluble dietary fiber content of 2.2–4.4 %, and total dietary fiber content of 7.0–8.5 %. Baye (2014) stated that teff flour contained 0.9 % soluble dietary fiber and 4.05 % total dietary fiber, while Hager et al. (2012) reported 0.85 % soluble dietary fiber and 4.50 % total dietary fiber.

Analysis results of the gluten-free boza are given in Table 3 and the rheological properties (*K* and *n*), pH values, and acidity degrees are also given in Table 3.

The data showed that the L value of boza decreased by 9.34 % with the buckwheat replacement and 25.93 % with the teff replacement. Besides, the substituted flours caused a darker color in the boza. When the *a* values of the boza were examined, there was a 2.98-fold increase after the replacement with teff. With the substitution of buckwheat flour, the *b* value of the boza increased at the rate of 43.80 %, and at 25.80 % with the substitution of teff. In other words, the redness and yellowness values of the boza increased with all substituted flour varieties. These changes were found to be statistically significant ($p < 0.05$).

In Çelik et al. (2016) analysis, the *L*, *a*, and *b* values of the obtained control boza were indicated as 51.70, 0.61, and 14.59, respectively. The differences between these values and the produced control boza in the present study result from the variety of raw materials used and the revisions in the production method. These results are close to the produced control boza in our study. Similar color results were reported in various products (cookies, biscuits, and bread) produced with buckwheat and teff flour. It was determined that these products had lower *L*, higher *a*, and higher *b* values for buckwheat products, and lower *b* values for teff products, compared to the control samples (Altındağ et al., 2015; Homem et al., 2020).

That data indicated that the control boza had the highest *K* value (4.92). Since the *K* value gives an idea about the product's consistency, the most viscous sample was the control boza. On the contrary, the boza with the lowest consistency value was substituted buckwheat (2.14). All the samples showed pseudo plastic flow behavior since the *n* value was below 1. This means that the viscosity decreases with increases of the shear rate. In an earlier study

Table 2: Physical and chemical properties of flours.

Flour Properties*	WF	BWF	TF
Composition (%)			
Ash	0.56±0.01c*	1.37±0.08b	2.09±0.01a
Protein	12.87±0.03b	13.98±0.08a	14.17±0.23a
Soluble Dietary Fiber	1.32±0.01b	1.54±0.02a	1.46±0.02a
Insoluble Dietary Fiber	1.53±0.02b	4.55±0.03a	1.62±0.01b
Total Dietary Fiber	2.85±0.03c	6.09±0.06a	3.08±0.01b
Color			
L (lightness)	87.95±0.03a**	82.28±0.05b	54.53±0.01c
a (redness)	-0.61±0.01c	0.46±0.01b	4.27±0.01a
b (yellowness)	8.14±0.03b	7.20±0.01c	9.93±0.04a

WF: Wheat Flour, BWF: Buckwheat Flour, TF: Teff Flour.
* Results are given on dry matter.
**Values of mean ± standard deviations with the same letter are not significantly different at $\alpha = 0.05$

Table 3: Analysis results of boza.

Boza Properties* Composition (%)**	COB	BUB	TEB	BTB	Traditional/Commercial boza
Moisture	76.07±0.44a*	74.66±0.33b	75.12±0.48b	75.06±0.36b	
Ash	0.51±0.02b	0.60±0.05a	0.52±0.03b	0.57±0.02ab	0.12-0.81 (Arici and Daglioglu, 2002)
Protein	3.45±0.03b	3.85±0.07a	3.90±0.16a	3.88±0.04a	0.90-1.22 (Arici and Daglioglu, 2002)
Lipid	0.29±0.02b	0.25±0.01b	0.43±0.02a	0.39±0.03a	
Soluble Dietary Fiber	0.78±0.03b*	1.00±0.05a	0.83±0.02b	0.92±0.02a	
Insoluble Dietary Fiber	1.26±0.01d	1.54±0.02a	1.33±0.02c	1.46±0.01b	
Total Dietary Fiber	2.04±0.02d	2.54±0.05a	2.16±0.04c	2.38±0.03b	1.3-17.6 (Petrova and Petrov, 2017)
Color					
L (lightness)	60.46±0.71a	54.81±1.52b	44.78±0.44d	49.92±0.20c	
a (redness)	-1.70±0.11d	-0.88±0.11c	3.37±0.03a	2.11±0.07b	
b (yellowness)	8.72±1.02c	12.54±0.72a	10.97±0.08b	11.85±0.11ab	
Viscosity					
K (Pa·s^n)	4.92±0.01a	2.14±0.01d	2.76±0.01b	2.43±0.01c	
n	0.36±0.01d	0.54±0.01a	0.42±0.01c	0.49±0.01b	
pH	3.35±0.01a	3.04±0.02c	3.33±0.01a	3.28±0.01b	
Acidity***	0.32±0.01c	0.43±0.01a	0.33±0.01c	0.37±0.01b	0.3-0.5 (Arici and Daglioglu, 2002)

COB: Control Boza, BUB: Buckwheat Flour Gluten-Free Boza, TEB: Teff Flour Gluten-Free Boza, BTB: Buckwheat Flour and Teff Flour Mix Gluten-Free Boza.
* Values of mean ± standard deviations with the same letter are not significantly different at $\alpha = 0.05$.
** Results are given on dry matter.
*** In terms of lactic acid.

(Hayta et al., 2001), boza was obtained with unfermented or fermented in different temperatures, and K values were reported between 1.02 and 4.21, with n values between 0.59 and 0.78. The control boza again had the highest K value in that study, which was also above the K values found in the present study. The n values were lower than in this study, but overall, the results were close to each other. This is explained by the fact that the gel-forming capacity of flours containing less starch is lower (İbanoğlu and İbanoğlu, 1999). The K and n values are in the given range. In Çelik et al. (2016) analyses, while the K values were reported to be much higher than the results of our gluten-free boza, the n values were similar to some gluten-free boza.

When the pH value of the boza was examined, it was determined that the buckwheat substituted gluten-free boza had the lowest pH value was, with the highest pH in the control and teff flour substituted gluten-free boza. In terms of acidity levels, the buckwheat flour substituted gluten-free boza had the highest and the control and teff boza had the lowest. These acidity grades and pH results are compatible with each other and confirm. Yücel and E. (2002) reported that the acidity degrees of 10 different boza types were in the range of 0.15–0.50 %, similar to the present study's results. On the other hand, in Uylaşer et al. (1998) study, the acidity degree of boza was specified as 0.18–0.34, and Heperkan et al. (2014) placed it in the range of 0.25–0.30. In our study, while the acidity levels of buckwheat flour boza samples were higher, the acidity levels of the control and teff boza were in the range given by Uylaşer et al. (1998), though they were higher than those reported by Heperkan et al. (2014).

The moisture amount of the control boza was higher than the others. While the moisture amount of all the gluten-free boza (BUB, TEB and BTB) was lower than the control boza, there was no significant difference between them ($p > 0.05$). The sample with the highest ash content was the buckwheat substituted boza. Ash amounts in the gluten-free boza substituted with teff flour and in the control boza were similar ($p > 0.05$). The ash and protein amount of gluten-free boza increased with buckwheat flour and teff substitutes. The effect of the substituted raw material type on the protein amount of the gluten-free boza was found to be statistically insignificant ($p > 0.05$). It was determined that the control boza and the buckwheat flour substituted gluten-free boza were similar in terms of oil content ($p > 0.05$). Substituting teff flour increased the amount of oil in the boza samples.

Yücel and E. (2002) reported that the dry matter content was between 17.26 %–22.32 % and the ash content was between 0.02 %–0.17 % across 10 different boza types. Our results showed that both the dry matter content and the ash content of the gluten-free boza were higher. Uylaşer et al. (1998) reported the dry matter content of boza in the range of 18.99–25.70 %, protein content of 0.27–0.56 %, and ash content of 0.07–0.17 %. While our gluten-free boza was within these ranges in terms of dry matter content, they are richer in terms of protein and ash. In another study, it was stated that the dry matter content of boza was between 14.39–24.07 %, protein content 0.46–0.65 %, and ash content 0.17–0.44 % (Heperkan et al., 2014). Compared to this study, control boza was in the given range in terms of the amount of dry matter.

The lowest content of soluble dietary fiber (0.78 %), insoluble dietary fiber (1.26 %), and total dietary fiber (2.04 %) was found in the control boza. The substitution of buckwheat flour increased soluble dietary fiber at the rate of 28.20 %, insoluble dietary fiber increased by 22.22 %, and total dietary fiber increased 24.50 % ($p < 0.05$). Gluten-free boza using buckwheat flour stands out as the richest sample in terms of dietary fiber content. It was determined that the substituted raw materials increased the dietary fiber content of boza, with a 6.41 % increase in soluble dietary fiber content of boza when just substituting teff flour, but that increase was not statistically significant ($p > 0.05$).

Borcaklı et al. (2018) reported that the dietary fiber content of the boza they produced with a mixture of wheat flour, corn flour, and millet flour was 2.52 %, while the dietary fiber content of boza produced with a mixture of wheat flour and corn flour was 4.11 %. In the present study, while the control boza contained lower total dietary fiber, all the samples contained higher total dietary fiber than the dietary fiber content (0.02–0.75 %) of the boza described by Bayat and Yıldız (2019) and Arıcı and Dağlıoğlu (2007). Mineral matter analysis results of the boza are given in Table 4. While the calcium content of boza decreased by 14.42 % with the substitution of buckwheat flour, it increased 94.32 % with the replacement of teff.

Mineral matter analysis results of the boza are given in Table 4. The substitution of buckwheat flour caused a decrease in the Fe content, while substituting teff flour increased the Fe content by 30.35 %. Substituted raw materials increased the K content of the boza. Boza produced with a mixture of buckwheat flour and teff flour, which generated an increase of 40.53 % in K content, was determined as the richest gluten-free boza type in terms of K content. With the substitution of teff flour, there was an increase of 6.49 % in the Na amount of the boza. These changes in Ca, Fe, K, and Na contents were not found to be statistically significant ($p > 0.05$). It was determined that there was an 83.72 % increase in the Mg content of the teff-substituted gluten-free boza. This increase was significant ($p < 0.05$).

While there was no significant difference in the Mn content of gluten-free boza with buckwheat flour ($p > 0.05$), there was a 6.86-times increase with teff flour substitution. This increase was statistically significant ($p < 0.05$). With the substitution of teff flour, the P content of gluten-free boza increased by 74.95 % and the Zn content increased 1.58 times. These increases made a significant difference ($p < 0.05$).

In their study, Öncel and Demir (2019) reported that noodles in which buckwheat flour was substituted by 30 % of the total amount contained 47.54 mg/100 g Ca, 217.55 mg/100 g K, 47.05 mg/100 g Mg, 0.70 mg/100 g Mn, 2.39 mg/100 g Fe, and 1.75 mg/100 g Zn in the formulation. In another study, it was stated that bread in which teff flour was substituted by 25 % contained 63.90 mg/100 g Ca, 171 mg/100 g K, 30.90 mg/100 g Mg, 1.04 mg/100 g Fe, 2.09 mg/100 g Mn, and 0.65 mg/100 g Zn Rybicka et al. (2019). Compared to our results, the Ca, Mg, and Fe content of buckwheat-substituted gluten-free boza was higher, while the content of Ca, K, Mg, Fe, and Zn of teff flour-substituted boza was higher. The control boza which was produced in the study by Çelik et al. (2016) had less mineral substance content than the control boza in our study. The differences are likely due to different formulations and raw material types of studies.

The results of microbiological analyses of our boza are given in Table 5, which shows that BUB had the highest number of LABs of all the gluten-free boza. Other types of boza have statistically similar ($p > 0.05$) and lower numbers of LABs than BUB. This difference also gave BUB the highest acidity and lowest pH value, perhaps because the LABs produced more lactic acid during fermentation. In terms of the YM and TMAB numbers, the lowest result was obtained from BUB, likely because high acidity limited the development of YM and TMAB more than in the other samples. Boza is a rich source of probiotic lactic acid bacteria and produced bacteriocins active against a number of pathogens (Todorov et al., 2008). Since LAB and yeast produce catalase enzyme that breaks

Table 4: Mineral matter analysis results of boza (mg/100 g).

Mineral Matter**	Boza Sample*			
	COB	BUB	TEB	BTB
Ca	89.03±3.49a***	76.19±15.72a	173.01±53.55a	117.37±5.70a
Fe	6.39±2.72a	4.20±1.01a	8.33±0.59a	5.87±0.62a
K	145.61±0.69a	196.30±21.34a	204.35±12.42a	204.64±15.64a
Mg	63.12±12.77b	81.71±4.83ab	115.97±1.66a	90.75±12.08ab
Mn	0.22±0.02c	0.25±0.07c	1.73±0.12a	1.09±0.07b
Na	46.19±3.47a	46.58±0.38a	49.19±5.16a	47.64±6.13a
P	182.69±5.91b	255.69±36.06ab	319.63±6.54a	292.08±6.56a
Zn	0.31±0.01b	0.39±0.08b	0.80±0.12a	0.51±0.06ab

* COB: Control boza, BUB: Buckwheat flour gluten-free boza, TEB: Teff flour gluten-free boza, BTB: Buckwheat flour and Teff flour mix gluten-free boza
** Results are given on dry matter.
*** Results indicated with different letters in the same column were found to be statistically significant ($p < 0.05$).

Table 5: Declared amount of energy and nutrient contents.

Boza samples	Microbiological Analysis*		
	LAB	YM	TMAB
COB	8.80±0.03b**	5.83±0.05ab	6.01±0.03a
BUB	8.91±0.02a	5.76±0.05b	5.64±0.03c
TEB	8.80±0.01b	6.14±0.27a	5.84±0.04b
BTB	8.80±0.02b	6.14±0.08a	5.87±0.03b

COB: Control Boza, BUB: Buckwheat Flour Gluten-Free Boza, TEB: Teff Flour Gluten-Free Boza, BTB: Buckwheat Flour and Teff Flour Mix Gluten-Free Boza.
* LAB: Lactic Acid Bacteria, YM: Yeast and Mold, TMAB: Total Mesophilic Aerobic Bacteria.
** Values of mean ± standard deviations with the same letter are not significantly different at $\alpha = 0.05$.

down hydrogen peroxide, increasing the effect on catalase-negative bifidobacterial (Arslan et al., 2015). Therefore, having more LABs have a positive effect on health.

According to past studies, the LAB numbers of boza that are controlled and sold commercially were indicated as 4.60×10^8 cfu/mL (Hancioğlu and Karapinar, 1997), 8.79 log cfu/mL (Zorba et al., 2003), 0.51–3.31 cfu/mL (Arıcı et al., 2014), and $1.20–9.62\times10^8$ cfu/mL (Uysal et al., 2009). Yeast counts were indicated as 3.05×10^5 cfu/mL–4.26×10^6 cfu/mL (Uysal et al., 2009), 3.71×10^3 cfu/mL–9.40×10^5 cfu/mL (Arıcı et al., 2014); 6.89 log cfu/mL (Zorba et al., 2003), and 8.10×10^6 cfu/mL (Hancioğlu and Karapinar, 1997). The number of TMAB was stated as 9.60×10^8 cfu/mL–5.80×10^9 cfu/mL (Uysal et al., 2009). Compared to our results, the LAB numbers of the produced gluten-free boza were in previously documented ranges but the number of TMABs was lower. The number of YM could not be compared since it was only given as the yeast number in the studies.

Sensory analysis results of the boza are given in Table 6. According to the results of the sensory analysis, the control boza got the highest score in terms of color and odor parameters. The effect of the substituted raw materials on the color property was found to be significant ($p < 0.05$), though the effect on the odor property was not significant ($p > 0.05$). The panelists gave the highest score to the BTB according to the flavor feature. For the consistency parameter, BUB and BTB got the highest scores. In the study of Çelik et al. (2016), a new boza formulation was developed using yellow chickpea flour and overall acceptance of new-formulated boza samples were between 3.30 and 4.90, while control boza had got a score of 4.35. Moreover, in a study conducted by Öztürk et al. (2013), a type of probiotic boza was produced using *Lactobacillus casei Shirota* and general acceptance of boza samples was between 5.8 and 6.6 out of 9 points on a sensorial rating scale. In our study, the type that earned the highest general taste score by the panelists was the gluten-free boza substituted with a mixture of buckwheat and teff flour. Therefore buckwheat and teff flours may be promising alternatives in the production of gluten-free functional boza.

Viell et al. (2020), who substituted teff flour in different proportions for a gluten-free bread formulation, reported that the color, taste, texture, and overall acceptance scores of the bread decreased with the substitution of teff flour.

4. Conclusions

Boza, a traditional Turkish fermented beverage, was produced in a gluten-free version for this study, contributing to the increase of gluten-free product ranges. Buckwheat and teff flour substitutes gave boza different functional properties as well as making it gluten-free. Usage of different gluten-free flours affected the properties of boza significantly. With the substituted raw materials, the dietary fiber and protein content of the boza increased, as did the amount of K, Mg, Mn, P, and Zn. Substituting these flours did decrease the viscosity of boza, but this decrease did not affect the sensory analysis results. The results of the sensory analysis show that gluten-free boza produced with buckwheat and teff flour mixture was the most popular type in terms of taste and overall acceptance characteristics. As a result, its nutritional value was

Table 6: Declared amount of energy and nutrient contents.

Boza samples*	Color (1-7 S***)	Odor (1-7 S)	Flavor (1-7 S)	Consistency (1-7 S)	Overall Acceptance (1-7 S)
COB	5.82±0.03a**	5.12±0.03a	5.17±0.03a	5.07±0.03a	4.95±0.07bc
BUB	5.45±0.01b	5.05±0.07a	4.97±0.03b	5.10±0.01a	5.02±0.10ab
TEB	4.37±0.03d	5.10±0.01a	4.92±0.03b	4.82±0.03a	4.75±0.01c
BTB	5.00±0.07c	4.95±0.07a	5.27±0.03a	5.10±0.14a	5.22±0.03a

* COB: Control boza, BUB: Buckwheat flour gluten-free boza, TEB: Teff flour gluten-free boza, BTB: Buckwheat flour and Teff flour mix gluten-free boza.
** Results indicated with different letters in the same column were found to be statistically significant ($p < 0.05$).
*** S: Score.

increased in comparison to traditional boza in terms of sensory properties.

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References

AACC (1995). *Approved Methods of the American Association of Cereal Chemists (Method 32-07) (9th ed.)*. AACC, St. Paul, MN, USA.

AACC (1999). *Approved Methods of the American Association of Cereal Chemists (Method 46-12) (11th ed.)*. St. Paul, MN, USA.

Altındağ, G., Certel, M., Erem, F., and İlknur Konak, Ü. (2015). Quality characteristics of gluten-free cookies made of buckwheat, corn, and rice flour with/without transglutaminase. *Food Sci. Technol. Int.*, 21(3):213–220.

Anonymus (1995). *The Manual of HunterLab Mini Scan XE Colorimeter*. HunterLab Cooperation, Virginia, USA.

AOAC (1990). *Official methods of analysis of the AOAC (15 th ed.)*. Association of Official Analytical Chemists, Rockville, MD, USA.

AOAC (1995). *Official methods of analysis of the AOAC (16 th ed.)*. Association of Official Analytical Chemists, Rockville, MD, USA.

Arbuckle, J. (2014). *IBM SPSS statistics 22 For Windows. User's Guide*.

Arici, M. and Daglioglu, O. (2002). Boza: A lactic acid fermented cereal beverage as a traditional Turkish food. *Food Rev. Int.*, 18(1):39–48.

Arslan, S., Durak, A. N., Erbas, M., Tanriverdi, E., and Gulcan, U. (2015). Determination of microbiological and chemical properties of probiotic boza and its consumer acceptability. *J. Am. Coll. Nutr.*, 34(1):56–64.

Arıcı, M. and Dağlıoğlu, O. (2007). Boza: Laktik Asit Fermantasyonu ile Üretilen Tahıl Kaynaklı Geleneksel Bir Türk Gıdası. *Basım, ed. Ahmet Nezihi Turan*, pages 76–88.

Arıcı, M., Ersöz, N., Toker, Ö., Yilmaz, M., Cankurt, H., Durak, M., and O., S. (2014). Microbiological, steady, and dynamic rheological characterization of boza samples: temperature sweep tests and applicability of the Cox–Merz rule. *Turkish J. Agric. For.*, 38:377–387.

Barretto, R., Buenavista, R. M., Rivera, J. L., Wang, S., Prasad, P. V., and Siliveru, K. (2021). Teff (Eragrostis tef) processing, utilization and future opportunities: A review. *Int. J. Food Sci. Technol.*, 56(7):3125–3137.

Bayat, G. and Yıldız, G. (2019). The special fermented Turkish drink: Boza. *J. Tour. Gastron. Stud.*, 7(4):2438–2446.

Baye, K. (2014). Teff: Nutrient composition and health benefits. *Int. Food Policy Res. Inst.*, 67.

Bhinder, S., Kaur, A., Singh, B., Yadav, M. P., and Singh, N. (2020). Proximate composition, amino acid profile, pasting and process characteristics of flour from different Tartary buckwheat varieties. *Food Res. Int.*, 130:108946.

Bhinder, S., Singh, B., Kaur, A., Singh, N., Kaur, M., Kumari, S., and Yadav, M. P. (2019). Effect of infrared roasting on antioxidant activity, phenolic composition and Maillard reaction products of Tartary buckwheat varieties. *Food Chem.*, 285:240–251.

Borcaklı, M., T., Ö., and Yeşilada, E. (2018). Cereal source and microbial consortia of the starter culture influence the chemical composition and physicochemical characteristics of boza. *Turkish J. Agric. For.*, 42(6):412–422.

Boss, C. and Fredeen, K. (2004). *Concepts, Instrumentation and Techniques in Inductively Coupled Plasma Optical Emission Spectrometry*. Perkin Elmer Inc., USA.

Brites, L. T. G. F., Rebellato, A. P., Meinhart, A. D., Godoy, H. T., and Steel, C. J. (2022). Antioxidant-enriched gluten-free bread made with buckwheat flour: Evaluation of technological and nutritional quality. *Cereal Chem.*, 99(5):995–1006.

Çelik, I., Işik, F., and Yilmaz, Y. (2016). Effect of roasted yellow chickpea (Leblebi) flour addition on chemical, rheological and sensory properties of boza. *J. Food Process. Preserv.*, 40(6):1400–1406.

Dizlek, H., Özer, M., İnanç, E., and Gül, H. (2009). Composition of buckwheat (Fagopyrum esculentum Moench) and its possible uses in food industry. *Gıda*, 34:317–324.

Ertop, M., Kutluk, K., Çoşkun, K., and S., C. (2016). A new approach for production of chips with food industry byproducts: Gluten enriched chips. *Acad. Food J.*, 14:398–406.

Gebru, Y. A., Kim, D.-W., Sbhatu, D. B., Abraha, H. B., Lee, J. W., Choi, Y. B., Kim, Y.-H., Kim, M.-K., and Kim, K.-P. (2021). Comparative analysis of total phenol, total flavonoid and in vitro antioxidant capacity of white and brown teff (Eragrostis tef), and identification of individual compounds using UPLC-qTOF-MS. *J. Food Meas. Charact.*, 15(6):5392–5407.

Göncü, A. and Çelik, I. (2020). Investigation of some properties of gluten-free tarhanas produced by red, green and yellow lentil whole flour. *Food Sci. Technol.*, 40(suppl 2):574–581.

Göncü, A., Sarı, H., and A.K., Ö. (2018). Health from the past: Boza. In *Int. Agric. Environ. Heal. Congr.*, pages 1377–1382.

Haas, R. V., Homem, R. V., Farias, D. V., Schmidt, H. d. O., Rockett, F. C., Venzke, J. G., Jomori, M. M., Kist, T. L., Rios, A. d. O., and de Oliveira, V. R. (2022). Potential of teff (Eragrostis tef) flour as an ingredient in gluten-free cakes: Chemical, technological and sensory quality. *Int. J. Food Sci. Technol.*, 57(4):2051–2059.

Hager, A.-S., Wolter, A., Jacob, F., Zannini, E., and Arendt, E. K. (2012). Nutritional properties and ultrastructure of commercial gluten free flours from different botanical sources compared to wheat flours. *J. Cereal Sci.*, 56(2):239–247.

Hancioğlu, Ö. and Karapinar, M. (1997). Microflora of Boza, a traditional fermented Turkish beverage. *Int. J. Food Microbiol.*, 35(3):271–274.

Hayta, M., Alpaslan, M., and Köse, E. (2001). The effect of fermentation on viscosity and protein solubility of Boza, a traditional cereal-based fermented Turkish beverage. *Eur. Food Res. Technol.*, 213(4-5):335–337.

Hayıt, F. and Gül, H. (2017). Effect of the buckwheat flour and transglutaminase addition on physical and textural properties of partially-baked frozen sourdough bread. *Mediterr. Agric. Sci.*, 30:113–119.

Heperkan, D., Daskaya-Dikmen, C., and Bayram, B. (2014). Evaluation of lactic acid bacterial strains of boza for their exopolysaccharide and enzyme production as a potential adjunct culture. *Process Biochem.*, 49(10):1587–1594.

Homem, R. V., dos Santos Joaquim, A., Pimentel da Silva, H., Mello Evangelista, S., Komeroski, M. R., Doneda, D., Rockett, F. C., de Oliveira Schmidt, H., Rios, A., Schäfer, L., Rodrigues, C., Kist, T., and de Oliveira, V. (2020). Effect of teff (Eragrostis tef) on chemical and technological quality of gluten-free breads. *J. Culin. Sci. Technol.*, 18(6):535–548.

İbanoğlu, S. and İbanoğlu, E. (1999). Rheological properties of cooked tarhana, a cereal-based soup. *Food Res. Int.*, 32(1):29–33.

İkizoğlu, E. (2018). *Investigation of use of quinoa, chia, teff, mungbean and buckwheat expired shelf life in the ruminant nutrition by in vitro methods*. PhD thesis, Namık Kemal Üniversitesi.

Kaplan, M., Üke, Ö., Kale, H., Yavuz, S., Kurt, Ö., and Atalay, A. (2016). Effect of vegetative stages on potential nutritive value, gas production and methane of teff hay. *Iğdır Univ. J. Inst. Sci. Tech.*, 6:181–186.

Klepacka, J. and Najda, A. (2021). Effect of commercial processing on polyphenols and antioxidant activity of buckwheat seeds. *Int. J. Food Sci. Technol.*, 56(2):661–670.

Kumari, S., Bhinder, S., Singh, B., Kaur, A., and Singh, N. (2020). Effect of buckwheat incorporation on batter fermentation, rheology, phenolic, amino acid composition and textural properties of idli. *LWT*, 122:109042.

Kılınççeker, O. and Karaman, A. (2019). Usage possibilities of teff (Eragrostic tef) seed flour in production of fish meatball. *J. ADYUTAYAM*, 7:27–35.

Levent, H. and Algan Cavuldak, Ö. (2017). A traditional fermented beverage: Boza. *Acad. Food J.*, 15:300–307.

McAllister, B. P., Williams, E., and Clarke, K. (2019). A comprehensive review of celiac disease/gluten-sensitive enteropathies. *Clin. Rev. Allergy Immunol.*, 57(2):226–243.

Nespeca, L. d. S., da Silva Paulino, H. F., Barlati Vieira da Silva, T., Bona, E., Leimann, F. V., Marques, L. L. M., Cardoso, F. A. R., Droval, A. A., and Fuchs, R. H. B. (2021). How does the replacement of rice flour with flours of higher nutritional quality impact the texture and sensory profile and acceptance of gluten-free chocolate cakes? *Int. J. Food Sci. Technol.*, 56(4):2019–2029.

Öncel, E. and Demir, M. (2019). Effect of pseudocereal flour substitution in formulation on properties of erişte, Turkish pasta product. *Acad. Food J.*, 17:468–475.

Öztürk, I., Karaman, S., Törnük, F., and Sağdıç, O. (2013). Physicochemical and rheological characteristics of alcohol free probiotic boza produced using Lactobacillus casei Shirota: Estimation of apparent viscosity of boza using non-linear modeling techniques. *Turkish J. Agric. For.*, 37:475–487.

Petrova, P. and Petrov, K. (2017). Traditional cereal beverage boza. In *Fermented Foods, Part II Technol. Interv.* CRC Press, Boca Raton, FL, USA.

Rico, D., Ronda, F., Villanueva, M., Perez Montero, C., and Martin-Diana, A. B. (2019). Development of healthy gluten-free crackers from white and brown tef (Eragrostis tef Zucc.) flours. *Heliyon*, 5(10):e02598.

Rybicka, I., Doba, K., and Bińczak, O. (2019). Improving the sensory and nutritional value of gluten-free bread. *Int. J. Food Sci. Technol.*, 54(9):2661–2667.

Sarı, U. and Tiryaki, I. (2018). An alternative cereal: Forgotten a new plant from the past. *KSU J. Agric Nat.*, 21:447–456.

Sedej, I., Sakač, M., Mandić, A., Mišan, A., Tumbas, V., and Hadnađev, M. (2011). Assessment of antioxidant activity and rheological properties of wheat and buckwheat milling fractions. *J. Cereal Sci.*, 54(3):347–353.

Singh, J. P., Kaur, A., Singh, B., Singh, N., and Singh, B. (2019). Physicochemical evaluation of corn extrudates containing varying buckwheat flour levels prepared at various extrusion temperatures. *J. Food Sci. Technol.*, 56(4):2205–2212.

Steadman, K., Burgoon, M., Lewis, B., Edwardson, S., and Obendorf, R. (2001). Buckwheat seed milling fractions: Description, macronutrient composition and dietary fibre. *J. Cereal Sci.*, 33(3):271–278.

Todorov, S., Botes, M., Guigas, C., Schillinger, U., Wiid, I., Wachsman, M., Holzapfel, W., and Dicks, L. (2008). Boza, a natural source of probiotic lactic acid bacteria. *J. Appl. Microbiol.*, 104:465–477.

Tomar, O., Çağlar, A., and G., A. (2020). Quality characteristics of tarhana produced with different ratios of whole wheat and buckwheat flour. *Gıda*, 45(3):421–432.

Topkaya, C. and Isik, F. (2019). Effects of pomegranate peel supplementation on chemical, physical, and nutritional properties of muffin cakes. *J. Food Process. Preserv.*, 43(6):e13868.

Tuluk, K. and N., E. (2019). The effects of different gluten-free flours on the physical, chemical, functional and sensorial properties of tarhana. *Harran Tarım ve Gıda Bilim. Derg.*, 23(3):301–312.

Turkish Standard (2002). *TS 1125 ISO 750, Fruit and vegetable products-determination of titratable acidity*. Turkish Standards Institution (TSE), Ankara, Türkiye.

Turkish Standard (2017). *TS-9778, Standard of Boza*. Turkish Standards Institution (TSE), Ankara, Türkiye.

USDA (2019a). Agricultural Research Service National Nutrient Database for Standard Branded, Buckwheat Flour.

USDA (2019b). Agricultural Research Service National Nutrient Database for Standard SR Legacy Tef, uncooked.

Uylaşer, V., Korukluoğlu, M., Göçmen, D., and Şahin, I. (1998). Bursa'da Satışa Sunulan Bozaların Bileşimi ve Kalitelerinin Araştırılması. *Gıda Mühendisliği Kongresi Gaziantep*, pages 135–141.

Uysal, Ü. D., Öncü, E. M., Berikten, D., Yilmaz, N., Tuncel, N. B., Kıvanc, M., and Tuncel, M. (2009). Time and temperature dependent microbiological and mycotoxin (ochratoxin-A) levels in boza. *Int. J. Food Microbiol.*, 130(1):43–48.

Viell, F. L. G., Tonon, G. C., Perinoto, L. C., Braga, M. L., Fuchs, R. H. B., Gomes, S. T. M., Bona, E., and Matsushita, M. (2020). Sensory characterization of gluten-free bread enriched with teff (Eragrostis tef (Zucc.) Trotter) and yacon (Smallanthus sonchifolius) using flash profile and common dimension analysis. *J. Food Process. Preserv.*, 44(2).

Woomer, J. S. and Adedeji, A. A. (2021). Current applications of gluten-free grains – a review. *Crit. Rev. Food Sci. Nutr.*, 61(1):14–24.

Yaver, E. and Bilgiçli, N. (2020). Pseudocereals: Composition, effect on nutrition-health and usage in cereal products. *Food Heal.*, 6:41–56.

Yücel, U. and E., K. (2002). A study on chemical composition of bozas produced in Izmir. *Food*, 27:395–398.

Yıldız, N. and Yalçın, E. (2013). Chemical, nutritional and technological properties of buckwheat. *Gıda*, 38:383–390.

Zorba, M., Hancioglu, O., Genc, M., Karapinar, M., and Ova, G. (2003). The use of starter cultures in the fermentation of boza, a traditional Turkish beverage. *Process Biochem.*, 38(10):1405–1411.