FOOD and HEALTH

FOOD and HEALTH
E-ISSN 2602-2834

Food and Health 10(2), 138-148 (2024) • https://doi.org/10.3153/FH24013 Research Article

Sensory evaluation of bread, rice pudding and cake incorporating germinated cereal and legume flour

Sena AKSU, Derya ALKAN

Cite this article as:
Aksu, S., Alkan, D. (2024). Sensory evaluation of bread, rice pudding and cake incorporating germinated cereal and legume flour. *Food and Health,* 10(2), 138-148. https://doi.org/10.3153/FH24013

Muğla Sıtkı Koçman University, Fethiye Faculty of Health Sciences, Department of Nutrition and Dietetics, Karaculha Street, 48300, Fethiye, Muğla, Türkiye

ORCID IDs of the authors:
S.A. 0009-0005-5602-1964
D.A. 0000-0003-0608-296X

Submitted: 12.10.2023
Revision requested: 11.01.2024
Last revision received: 25.01.2024
Accepted: 20.03.2024
Published online: 31.03.2024

Correspondence:
Derya ALKAN
E-mail: deryaalkan@mu.edu.tr

ABSTRACT

The germination process of cereal and legumes has been used to improve their nutritional value. In this study, sorghum, oat, mung bean and barley were germinated for 96 hours. Dry matter, total ash content and phenolic content analyses of germinated samples were performed. Sprouts of germinated grains and legumes were dried and ground into flour. The obtained flour was used in the production of bread (20-40%), cake (5-15%) and rice pudding (10%). In the prepared bread, % baking loss and specific volume were calculated, and sensory analyses of rice pudding, gluten-free cake and bread samples were carried out. All samples' dry matter contents except sorghum decreased by the germination process. Germination caused a slight increase in ash contents of all samples except for barley. The total phenolic contents of mung bean and barley significantly increased during germination. All sprout flours added at 40% reduced the specific volume of the bread. Based on the results, it can be concluded that products with a substitution of sorghum sprout flour were more acceptable in sensorial properties compared to other samples. It can be concluded that it is feasible to produce high nutritional value tasty functional foods with germinated sorghum flour supplementation.

Keywords: Sensory analysis, Germination, Food enrichment, Sprouting, Gluten-free foods

Introduction

Cereals and legumes are traditionally consumed as an important part of diets in many cultures. They contribute significantly to people's nutrient intake and provide complementary health benefits. They are important sources of macronutrients, micronutrients, phytochemicals, and antinutritional factors. Storage conditions and postharvest treatments such as germination and fermentation cause significant biochemical changes affecting the nutritive value of cereal and legume grains (Miyahira et al., 2021; Nkhata et al., 2018).

Edible sprouts are obtained by germination, which occurs at the beginning of the development of seeds into plants. Many studies have examined the effect of the germination process on proximate and micronutrient composition, phytonutrient contents, the presence of anti-nutritional factors, and overall food quality (Domínguez-Arispuro et al., 2018; Malik et al., 2021). During the germination process, important biochemical events, such as the synthesis of some vitamins, minerals, and phenolic substances in the bodies of plants and seeds, as well as the change in protein, carbohydrates, and fatty acid compositions, occur.

Sprouted seeds are popular worldwide due to the consumer demand for natural or low-processing and additive-free foods rich in vitamins, minerals, bioactive components and antioxidant substances to lead a healthy life (Benincasa et al., 2019). Sprouted seeds could also be used to enhance the sensorial properties of different food products due to their rich content of bioactive substances and characteristics of colour, flavour and aroma. The occurrence of some biochemical modifications during the germination of seeds affects some attributes such as bioactivity, digestibility, and nutrient content. It contributes to the enhancement of organoleptic properties such as consistency and flavour. Therefore, if these sprouted seeds can be used in traditional foods, they could enhance sensory and textural properties and nutritional traits, that is protein, dietary fibre, phenolic, mineral and vitamin content (Ikram et al., 2021; Kumari et al., 2021).

This study aimed to establish the influence of the germination process on ash and dry matter contents of some cereals and legumes such as sorghum, oat, mung bean and barley. Besides these, the total phenolic contents of the samples were investigated. In order to reveal the possibilities of using germinated cereal and legume seeds as food additives, sprouted grains were also dried and turned into flour. Germinated flour samples were used to produce bread, cake, and rice pudding at certain levels, and the obtained products were evaluated in terms of sensorial properties. The possibility of using them as a natural additive in some processed foods will create a good opportunity for the consumption of sprouted products in the world.

Materials and Methods

Germination Process

Sorghum, oat, mung bean and barley were obtained from the local market in Fethiye, Muğla. The samples were kept in a 1:5 ratio of ethanol (70%) for 10 min to provide sterilisation (Cevallos-Casals & Cisneros-Zevallos, 2010). The sterilised cereal and legume grains were soaked in pure water (1:3) at room temperature (24 ± 1 °C) for 24 h in darkness. The water was drained, and the grains germinated at room temperature for 96 h. Furthermore, the grains were moistened twice daily with distilled water during the germination. Grains with a sprout length of 1 mm or more were considered germinated. Before analysis, they were dried overnight at 50-55 °C in a drying oven (Nüve NF-1200R, Ankara, Turkey) and then milled into powder using a laboratory-type grinder (Briz-BR721). The ground grains were stored at -20 °C in locked polyethene bags until analyses.

Chemical Analyzes

The raw and germinated seeds' dry matter (DM) content was determined gravimetrically by drying them to a constant weight at 105 °C in the drying oven (Tarasevičienė et al., 2009). After dehydration, the dry weight was measured, and the percentage of dry matter content was calculated using Equation 1. Dry matter determination was repeated three times per sample.

$$DM\% = \text{Dry weight} / \text{Wet weight} \times 100 \quad (1)$$

For ash determination, approximately 5 g of dried samples were carbonised in the muffle furnace (Protherm furnaces, PLF 110/6) at 550 ºC for 6 h until white ash was obtained (Warle et al., 2015). The percentage of ash content was calculated by using Equation 2. Ash determination was repeated three times per sample.

$$Ash\% = \text{Ash weight} / \text{Sample weight} \times 100 \quad (2)$$

Determination of Total Phenolic Content

The extraction of phenols from raw and germinated samples was carried out according to the method described by Zhu et al. (2005) with some modifications. The one gram of sample was mixed with 10 mL of methanol solution (80% v/v) for 2 h, then centrifuged at 7000 rpm for 10 min, and the supernatant was obtained. The total phenolic content (TPC) of raw and germinated samples was determined using the Folin-Ciocalteu reagent described in the study of Singleton and Rossi (1965). The absorbance was measured at 765 nm using a spectrophotometer (Agilent Cary 60 UV-Vis). Phenolic content was expressed as mg of gallic acid (GA) equivalents per gr of the extract (mg/GAE g).

Production of Rice Pudding, Cake and Bread Samples

Rice pudding was prepared by mixing whole milk (200 mL), rice flour (7 g), corn starch (1 g), sugar (9 g), and sprouted legumes (5% and 15%). The mixtures were heated to 95 °C, held at 95 °C for 10 min, and cooled to 35 °C. Control rice pudding samples were prepared without sprouted grain and legume flour. Rice pudding samples are shown in Figure 1.

Cake flour mix was prepared with corn starch (45%), rice starch (45%) and germinated cereal and legume flour (10%). In order to prepare the cake mix, baking powder (3 g) and vanilla (3 g) were added to the cake mixture prepared with cake flour mixture (125 g), whole egg (125 g), oil (125 g) and sugar (125 g). Cake dough (40 g) was baked in the oven at 220 °C for 20 min. All analyses were performed within 24 hours after cooking.

The ingredients used in the production of germinated grain and pulse flour added bread are shown in Table 1. Percentages of ingredients are expressed over 100 g of flour. In the production of bread, germinated cereal and grain flour were used in the mixture of flour and starch at a rate of 20 and 40%, and the rest of this mixture consisted of brown rice flour and potato starch. The dough was mixed by adding starch, salt, sugar, sunflower oil, dry yeast, guar gum and water to the flour mixture. The dough was fermented at 30 °C at 70-75 % relative humidity for 15 min after being homogenised and divided into equal parts; it was subjected to a second fermentation for 20 min under the same conditions. Breads were baked in a convection oven at 220 °C for 30 min and left at room temperature for 1 hour to cool (Barışık & Tavman, 2019). All analyses were performed within 24 hours after cooking. Bread samples are shown in Figure 1.

Table 1. Ingredients used in the production of bread samples with the addition of germinated cereal and legume flour

Ingredients	Bread Samples		
	A (Control)	B (20%)	C (40%)
Germinated cereal and legume seed flour amount (g)	-	20	40
Brown rice flour (g)	50	40	30
Potato starch (g)	50	40	30
Salt (g)	1.5	1.5	1.5
Sugar (g)	3	3	3
Sunflower oil (g)	4	4	4
Yeast (g)	2	2	2
Guar gum (g)	1	1	1
Water (g)	90	90	90

Figure 1. Bread and rice pudding samples containing germinated cereal and legume flour

Bread Analyzes

For the determination of baking loss, after the breads were cut into equal parts and cooled, they were weighed. Measurements were repeated three times for each bread sample. The % baking loss was calculated by using Equation 5.

Baking Loss (%) = ((Initial dough weight - Bread weight) x 100 / Initial dough weight) (5)

For the determination of specific volume, after the bread weights were recorded, the volume covered by the rapeseed was determined by measuring the amount of rapeseed in cm^3 overflowing from the measuring cup. The bread-specific volume will be expressed as cm^3 /g by dividing the determined volume value by the bread weight (Cansız, 2018).

Sensorial Analysis

Produced rice pudding, cake and bread samples were used for the sensory and preference tests (Paiva et al., 2022). Twenty adult and healthy panellists from the Fethiye Faculty of Health Sciences participated in the sensory and preference panel. The panellists were informed about the details and implications of participating in the experiment. A written consent was obtained from all participants. For all rice pudding, cake and bread samples, the participants took the preference test of appearance, aroma, taste, colour, texture and overall acceptability using a 5-point hedonic scale (1: Extremely dislike, 5: Extremely like). The ranking test cake and bread samples were performed based on bread crumb colour, hardness and taste (1: least or lightest, 5: most or darkest for cake; 1: least or lightest, 9: most or darkest for bread). This procedure was applied with the permission of Muğla Sıtkı Koçman University Ethics Committee.

Statistical Analysis

Data from parallel measurements obtained from the physicochemical and sensory properties of the studied samples were expressed as mean ± standard deviation (SD). All data were analysed by one-way analyses of variance using the IBM SPSS Statistical Software (SPSS 22 Inc. Chicago, IL, USA). The significant means were compared by Tukey's multiple range tests ($p<0.05$). The effect of germination on the dry matter, ash and total phenolic contents of studied cereal and legume was evaluated by independent t-test ($P<0.05$).

Results and Discussion

Dry Matter, Ash, and Total Phenolic Content Results

The effect of germination on the dry matter, ash and total phenolic contents of studied samples are presented in Table 2. While no significant difference was observed in the dry matter content of raw and germinated sorghum, a statistically significant decrease ($P<0.05$) was found for the dry matter contents of oat, mung bean and barley samples by 96 h of germination. Similar changes in the dry matter content were reported during sorghum, barley, mung bean, and oat germination (Paiva et al., 2022; Farooquiet al., 2018; Wongsiriet al., 2015; Rani et al., 2022). The decrease in dry matter content is probably a result of the hydration of more cells with the growth of the seedling during germination. Applied pre-germination processes such as washing and soaking facilitate water absorption and consequently cause a decrease in dry matter (Malik et al., 2021).

The ash contents of sorghum, oat and mung bean samples were not significantly (P>0.05) affected by the germination process. However, it was observed that there was a slight increase in the ash content of these samples. According to Table 2, the germination process significantly (P<0.05) decreased the ash content of barley (from 3.08% to 1.16%). This result is similar to the findings reported by Islam et al. (2021), which declared that the ash content of soaked waxy barley seeds was lower than that of raw ones. Increasing ash content was reported by Fayyaz et al. (2018) and Xu et al. (2019) for germinated mung bean, and Tizazu et al. (2011) for germinated sorghum.

The results showed that the amount of TPC increased significantly for mung bean (about 116%) and barley (about 74%) after germination (Table 2). These results are in agreement with the results of Gan et al. (2016) and Lotfy et al. (2021), who stated that phenolic contents of mung bean and barley increased after germination because of the increasing activity of the phenylalanine ammonia-lyase (PAL) enzyme during sprouting. Table 2 further showed that while germination did not cause a significant change (P>0.05) in the total phenolic content of oats, it caused a significant decrease (P<0.05) in that of sorghum. Unlike our study, Arouna et al. (2020) found similar TPC in the non-germinated and germinated sorghum extracts, suggesting that germination did not influence the TPC in sorghum. They concluded that the effect of germination on the abundance of sorghum phenolic compounds could depend on sorghum varieties and germination conditions. In the study of Tok and Ertas (2021), wheat, rye and green lentil seeds flours were substituted for wheat flour at different ratios (0, 5, 10 and 15%) in bread making, and bread's nutritional and functional properties were investigated. It has been reported that using sprouted flour in bread formulation leads to a higher total phenolic content than the control sample.

Specific Colume and Baking Loss Results

Specific volume is an important factor in increasing the overall acceptability of bread. The specific volume and baking loss (%) results of bread samples produced by adding 20% and 40% of the flour of germinated grains and legumes are given in Figure 2. According to the results, it was determined that there was no statistically significant (p>0.05) effect of the addition of sorghum, barley, and oat flour on the specific volume of the control bread sample. However, adding germinated mung bean flour at 20% in bread increased the specific volume from 1.79 cm^3/g to 3.02. All sprout flours added at 40% reduced the specific volume of the bread. The specific volume of bread samples decreased with increasing germinated seed flour substitution levels (Figure 2). These findings are similar to observations by Sibanda et al. (2015), who observed that adding sorghum flour to wheat flour reduces the bread volume. Atudorei et al. (2023) highlighted that the varying proportions of the germinated soybean flour addition in bread recipes influenced the specific volumes of the bread samples differently. In this study, at an additional level of 20% germinated sorghum and mung bean flour, the specific volume of the bread samples was higher than that for the control samples. Conversely, the specific volumes of all bread samples decreased at 40% germinated sorghum, barley, oat, and mung bean flour supplementation in the bread.

Table 2. Dry matter, ash and total phenolic contents of raw and germinated cereal and legume

Samples		Dry Matter (%)		Ash (%)		TPC (mg GAE/g sample (dry matter))	
Sorghum	Raw	90.19±0.20		0.97±0.49		75.52±4.47	
	Germinated	90.35±0.26	P=0.453	1.02±0.21	P=0.861	19.23±2.69	*P=0.000
Oat	Raw	93.84±0.84		1.40±1.18		34.87±7.55	
	Germinated	88.51±0.34	*P=0.001	2.01±0.72	P=0.490	34.57±8.63	P=0.930
Mungbean	Raw	90.18±0.43		2.50±0.68		24.50±4.72	
	Germinated	85.42±0.05	*P=0.000	3.10±0.49	P=0.283	53.04±2.76	*P=0.000
Barley	Raw	92.22±0.19		3.08±0.12		42.19±4.96	
	Germinated	82.23±4.92	*P=0.025	1.16±0.64	*P=0.007	73.31±4.01	*P=0.000

Results are presented as mean ± standard deviation (SD)
*Significant differences between raw and germinated samples for each cereal and legume type (P < 0.05) by independent t-test

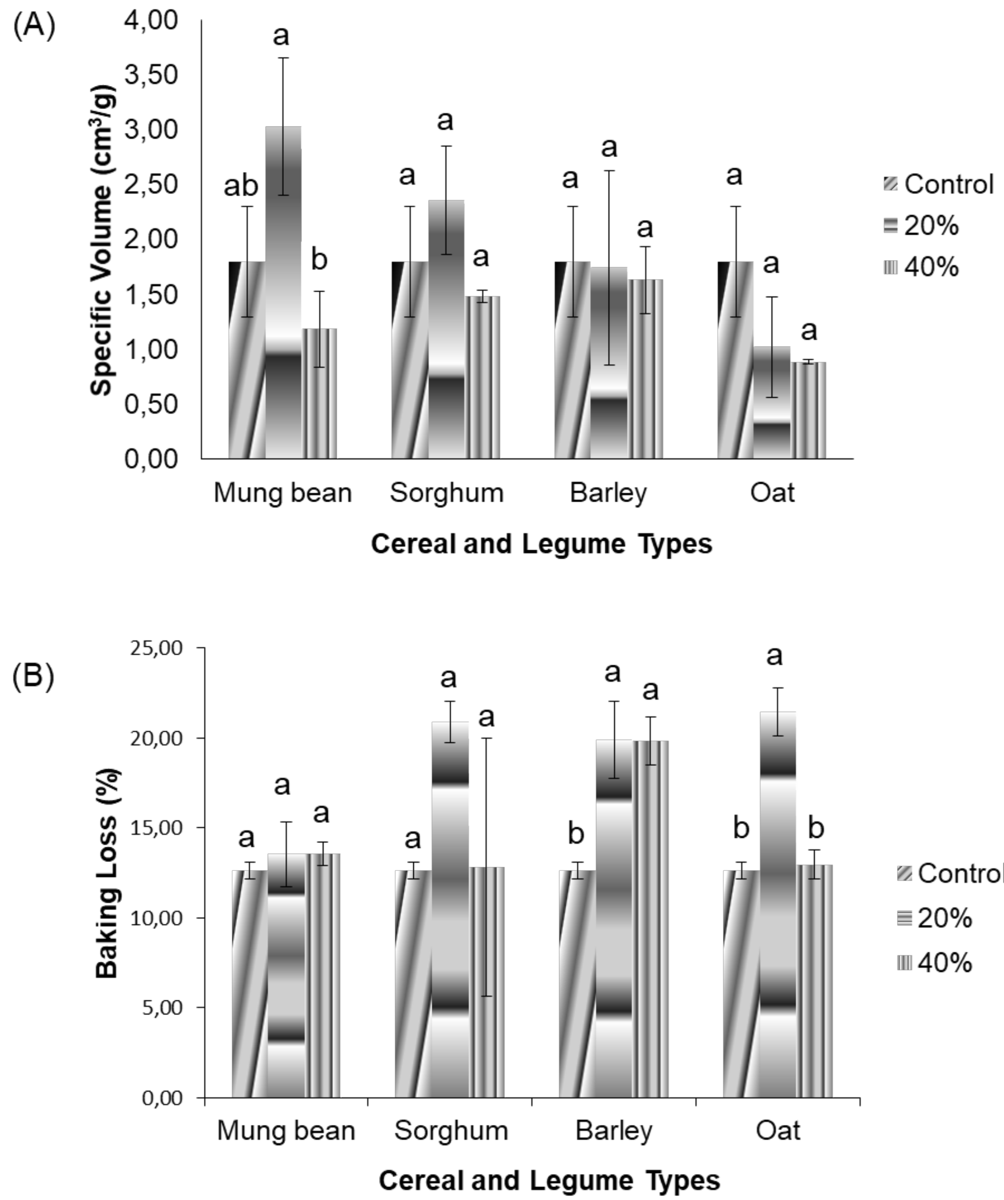

Figure 2. Results of (A) specific volume (cm^3/g) and (B) baking loss (%) analyses of bread samples. Results are presented as mean ± standard deviation (SD), and different letters for each cereal and legume indicate statistically significant differences (p<0.05) by Tukey's multiple range test.

Considering the baking loss results of the bread, it was determined that the type and rate of cereal and legume sprouts added had a statistically significant ($p<0.05$) effect on the baking loss values of the bread. The baking loss of the control sample was determined as 12,64%. The baking loss value of bread obtained by adding 20% of germinated oat flour (21.45%) significantly differed from the control sample. There was no statistically significant ($p>0.05$) difference in baking loss between the germinated mung bean and sorghum flour-added bread samples and the control bread samples. Bread from germinated barley flour had higher baking loss values than control bread samples ($p<0.05$). Increasing baking loss values are similar to those recorded in bread made from germinated barley, as Al-Ansi et al. (2022) reported. The increase could be explained by the degradation of protein and starch granules during germination.

Sensorial Analysis Results

The sensory scores of cake and bread samples produced from germinated cereal and legume flour are shown in Table 3. Generally, adding mung bean sprout flour significantly affected cake samples' colour, hardness and taste attributes. Adding mung bean flour caused a darker colour and harder texture in the cake samples compared to the control samples. The cake sample substituted with 10% mung bean sprout flour had the lowest mean taste score (2.05) among cake samples. As seen in Table 3, the substitution of sorghum sprout flour with 10% caused a favourable influence on cake colour, hardness and taste attributes. These cake samples showed significantly lower colour and hardness scores than control samples. Scores ranged from 1.60, 1.90 and 3.88 for colour, hardness and taste, respectively, while the control samples had 3.33, 3.43 and 3.28 scores for colour, hardness and taste, respectively. The study by Ayoubi et al. (2022) showed that adding pomegranate seed powder to cakes at levels above 5% has undesirable effects on sensorial acceptability. The sensory evaluation based on the ranking and hedonic scale tests revealed that the cake sample prepared with 10% germinated sorghum flour was more acceptable than the control sample. Gadallah (2017) reported that sorghum flour at 20-30 % and germinated chickpea flour at 20% as a substitution for rice flour in gluten-free cake processing produced desirable sensory gluten-free cakes with high consumer acceptance.

Based on the results, adding germinated mung bean flour at 40% hurt the final bread product in terms of colour, hardness and taste. By adding mung bean sprout flour at 40% into bread, bread samples' hardness and colour scores were significantly ($p<0.05$) increased while their taste scores were reduced compared to the control. Bread samples containing germinated oat flour at 20% were found to have the lightest colour (2.78) following control (1.00). Bread samples incorporated with germinated sorghum flour at 20% received the highest mean taste score of 6.45. Control bread was evaluated as the softest sample (2.43) by the panellists, followed by the bread sample containing sorghum sprout flour at a 20% rate (3.88). Levels of 10, 20, and 30% sorghum flour in wheat bread cannot significantly affect the composite bread's taste, flavour, and texture (Ognean, 2015). However, composite bread's sensory properties decreased as sorghum flour levels increased from 20 to 30 and 40% (Keregero & Mtebe, 1994).

Table 3. Results of ranking test of cake and bread samples

Sample			Colour	Hardness	Taste
Cake	Control	-	$3.33±1.49^{b}$	$3.43±1.45^{ab}$	$3.28±1.43^{ab}$
	Sorghum	10%	$1.60±0.84^{d}$	$1.90±0.96^{d}$	$3.88±1.11^{a}$
	Barley	10%	$2.98±1.00^{bc}$	$2.50±1.30^{cd}$	$2.90±1.37^{b}$
	Oat	10%	$2.65±1.10^{c}$	$3.10±1.08^{bc}$	$2.90±1.26^{b}$
	Mungbean	10%	$4.48±0.75^{a}$	$4.08±1.23^{a}$	$2.05±1.30^{c}$
Bread	Control	-	$1.00±0.00^{g}$	$2.43±2.32^{d}$	$6.18±2.74^{ab}$
	Sorghum	20%	$3.80±1.80^{e}$	$3.88±2.60^{cd}$	$6.45±2.51^{a}$
		40%	$6.43±1.20^{c}$	$6.18±2.48^{a}$	$4.68±2.18^{bcd}$
	Barley	20%	$3.83±1.28^{e}$	$4.38±2.12^{bc}$	$5.80±2.39^{abc}$
		40%	$5.18±1.48^{d}$	$4.55±1.83^{bc}$	$4.40±2.02^{cd}$
	Oat	20%	$2.78±1.05^{f}$	$6.28±2.15^{a}$	$4.88±2.22^{abcd}$
		40%	$5.83±1.32^{cd}$	$5.18±2.44^{abc}$	$4.45±2.41^{cd}$
	Mungbean	20%	$7.28±1.11^{b}$	$5.85±2.52^{ab}$	$5.00±2.34^{abc}$
		40%	$8.98±0.16^{a}$	$6.30±2.05^{a}$	$3.20±3.00^{d}$

Results are presented as mean ± standard deviation (SD), and different letters within columns (containing cake and bread samples separately) indicate statistically significant differences ($p<0.05$) by Tukey's multiple range test.

Table 4. Sensory evaluation of rice pudding, cake and bread samples

Sample			Appearance	Aroma	Taste	Texture	Colour	General Acceptability
Rice pudding	Control	-	4.73±0.51^{a}	4.08±0.92^{a}	4.10±0.93^{a}	4.35±0.86^{a}	4.95±0.22^{a}	4.48±0.72^{a}
	Sorghum	5%	3.35±1.12^{b}	3.68±0.97^{a}	3.93±0.73^{a}	3.18±1.30^{b}	3.53±0.82^{b}	3.73±0.82^{b}
		15%	2.68±1.07^{bc}	2.73±0.93^{b}	2.78±1.00^{b}	2.30±1.18^{c}	3.03±1.00^{bc}	2.68±1.07^{c}
	Barley	5%	2.40±1.17^{cd}	1.95±1.09^{c}	2.08±1.02^{c}	1.78±0.80^{c}	2.95±1.24^{bc}	2.13±0.99^{cd}
		15%	2.73±1.03^{bc}	1.68±0.83^{cde}	1.73±0.91^{cd}	2.38±1.13^{c}	2.85±1.10^{bc}	1.85±0.92^{de}
	Oat	5%	2.28±0.96^{cd}	1.30±0.56^{de}	1.40±0.63^{d}	1.98±1.07^{c}	2.53±1.09^{cd}	1.78±0.73^{de}
		15%	2.15±0.98^{cd}	1.13±0.40^{e}	1.20±0.56^{d}	1.68±0.86^{c}	2.08±0.97^{de}	1.30±0.61^{e}
	Mungbean	5%	1.93±0.97^{d}	2.15±0.98^{bc}	2.20±0.99^{bc}	2.28±1.06^{c}	2.08±1.07^{de}	2.13±0.99^{cd}
		15%	1.80±0.94^{d}	1.80±0.99^{cd}	1.75±0.95^{cd}	2.05±1.09^{c}	1.75±1.10^{e}	1.78±0.95^{de}
Cake	Control	-	3.23±1.07^{b}	3.83±1.08^{a}	3.83±1.08^{a}	3.45±1.15^{ab}	3.35±1.12^{b}	3.48±1.09^{b}
	Sorghum	10%	4.30±1.02^{a}	4.00±0.96^{a}	4.03±1.05^{a}	3.73±1.13^{a}	4.30±0.88^{a}	4.08±0.76^{a}
	Barley	10%	3.65±1.05^{ab}	3.68±1.12^{a}	3.55±1.20^{ab}	3.35±1.19^{ab}	3.65±1.15^{ab}	3.65±0.95^{ab}
	Oat	10%	3.60±1.08^{b}	3.68±1.02^{a}	3.68±1.10^{a}	3.50±1.01^{a}	3.68±1.12^{ab}	3.55±0.90^{ab}
	Mungbean	10%	3.25±1.06^{b}	2.88±1.24^{b}	2.98±1.17^{b}	2.83±0.96^{b}	3.15±1.08^{b}	3.13±1.11^{b}
Bread	Control	-	3.55±1.40^{bc}	4.03±1.00^{a}	4.08±0.97^{a}	3.95±1.09^{a}	3.38±1.55^{bc}	3.93±1.07^{ab}
	Sorghum	20%	4.33±0.94^{a}	4.08±0.86^{a}	4.15±0.87^{a}	3.85±1.10^{a}	4.10±1.11^{ab}	4.21±0.83^{a}
		40%	3.63±1.03^{abc}	3.48±1.15^{ab}	3.55±1.15^{ab}	2.85±1.21^{b}	3.78±1.12^{ab}	3.53±0.99^{b}
	Barley	20%	4.28±0.68^{ab}	3.83±1.15^{ab}	3.93±1.12^{a}	3.53±1.01^{ab}	4.35±0.70^{a}	3.95±0.85^{ab}
		40%	3.68±1.16^{abc}	3.20±1.24^{b}	3.10±1.13^{b}	3.45±1.11^{ab}	3.88±1.09^{ab}	3.35±1.12^{b}
	Oat	20%	3.48±1.22^{c}	3.70±1.07^{ab}	3.70±1.09^{ab}	3.25±1.08^{ab}	3.85±1.15^{ab}	3.70±0.85^{ab}
		40%	3.70±0.99^{abc}	3.20±1.07^{b}	3.08±1.02^{b}	3.48±1.01^{ab}	3.85±0.89^{ab}	3.38±0.90^{b}
	Mungbean	20%	3.68±0.89^{abc}	3.63±1.05^{ab}	3.48±1.06^{ab}	3.38±1.13^{ab}	3.38±1.23^{bc}	3.53±1.04^{b}
		40%	3.08±1.31^{c}	2.35±1.35^{c}	2.18±1.26^{c}	2.80±1.31^{b}	2.83±1.45^{c}	2.60±1.26^{c}

Results are presented as mean ± standard deviation (SD), and different letters within columns (containing rice pudding, cake and bread samples separately) indicate statistically significant differences ($p<0.05$) by Tukey's multiple range test.

Table 4 summarises the mean scores of hedonic sensory evaluation for appearance, aroma, taste, texture, colour and general acceptability of the rice pudding, cake and bread samples. The highest rating scores were recorded for the cake sample with the addition of sorghum sprout flour at 10% in all sensory characteristics, including general acceptability. The addition of 10% mung bean sprout flour in cake mixing resulted in lower scores than the control in all sensory characteristics except for appearance. The cake sample prepared with germinated mung bean flour received the lowest scores from the panellists in all sensory attributes evaluated. Hossain et al. (2014) developed a nutritionally enriched bakery product with jackfruit seed flour supplementation to wheat flour. They found that composite products with different levels of jackfruit seed powder were nutritionally better than the control sample. However, a significant decrease in colour, flavour, texture, taste and overall acceptability of products was observed with the increase in substitution.

Similarly, bread samples incorporated with 40% germinated mung bean flour had the lowest scores in all the attributes evaluated compared to the control. It ranged from 3.08, 2.35, 2.18, 2.80, 2.83, and 2.60 for appearance, aroma, taste, texture, colour and general acceptability, respectively, while the control had scores of 3.55, 4.03, 4.08, 3.95, 3.38 and 3.93, respectively. At the same time, the bread samples prepared with the addition of sorghum sprout flour at 20% obtained an excellent evaluation in terms of all sensory characteristics, including general acceptability. The literature has stated that using small amounts of sorghum flour with wheat flour can produce bread of similar quality to wheat flour. While the physicochemical and rheological qualities of bread produced using the combination of wheat and sorghum flour may be negatively affected, its sensory quality is acceptable (Akın et al., 2022).

The panellist generally accepted the control rice pudding sample, followed by the sorghum sprout flour incorporated rice pudding sample (5%). In terms of appearance and colour, the worst sample was the rice pudding sample with the addition of germinated mung bean flour at 15%. However, the worst sample in terms of aroma, taste, texture and general acceptability is a rice pudding sample containing germinated oat flour at 15%.

Our results from this study are supported by Riaz et al. (2007), who concluded that the overall acceptability of bread supplemented with mung bean at high levels was lower than that of whole wheat flour bread. It was clear that the control rice pudding sample had the highest values in all sensory scores compared to rice puddings supplemented with different cereal and legume sprout flour. It was noticed that using sorghum sprout flour at a substitution level of 5% in rice pudding caused higher sensorial and acceptability scores than other substituted treatments.

Conclusion

This study showed that supplementing germinated seed flour into some food products has great potential in developing functional products despite affecting sensory qualities. Adding 20% sorghum sprout flour resulted in bread and cake with good overall acceptability and a higher specific volume than the control sample. At the same time, the lowest baking loss value was found in bread containing 40% germinated sorghum flour. Based on the sensory evaluation of rice pudding, it can be concluded that sorghum sprout flour at a substitution level of 5% in rice pudding was acceptable.

Adding germinated sorghum flour to the formula of food products to improve their nutritional and functional properties will be a real and valuable method to contribute to human food diversification. Future studies will be needed to evaluate the effect of other germinated grains and legumes on the quality and consumer acceptance of functional products.

Compliance with Ethical Standards

Conflict of interest: The author(s) declare that they have no actual, potential, or perceived conflict of interest regarding this article.

Ethics committee approval: Sensory analysis in this study was carried out with the permission of Muğla Sıtkı Koçman University Ethics Committee (Approval no: 210047).

Data availability: Data will be made available on request.

Funding: This project was supported by TUBITAK, the Scientific and Technical Research Council of Turkey (project ID: TUBITAK-2209A-1919B012100623).

Acknowledgements: We appreciate the Fethiye Faculty of Health Sciences at Muğla Sıtkı Koçman University for allowing us to use their laboratory facilities.

Disclosure: -

References

Akın, P.A., Demirkesen, I., Bean, S.R., Aramouni, F., Boyacı, I.H. (2022). Sorghum flour application in bread: Technological challenges and opportunities. *Foods*, 11, 466. https://doi.org/10.3390/foods11162466

Al-Ansi, W., Zhang, Y., Alkawry, T.A.A., Al-Adeeb, A., Mahdi, A.A., Al-Maqtari, Q.A. (2022). Influence of germination on bread-making behaviours, functional and shelf-life properties, and overall quality of highland barley bread. *LWT Food Science and Technology*, 159, 113200. https://doi.org/10.1016/j.lwt.2022.113200

Arouna, N., Gabriele, M., Pucci, L. (2020). The impact of germination on sorghum nutraceutical properties. *Foods*, 9(9),1218. https://doi.org/10.3390/foods9091218

Atudorei, D., Mironeasa, S., Codină, G.G. (2023). Dough rheological behavior and bread quality as affected by addition of soybean flour in a germinated form. *Foods*, 12(6), 1316. https://doi.org/10.3390/foods12061316

Ayoubi, A., Balvardi, M., Akhavan, H.R., Hajimohammadi-Farimani, R. (2022). Fortified cake with pomegranate seed powder as a functional product. *Journal of Food Science and Technology*, 59(1), 308–316. https://doi.org/10.1007/s13197-021-05016-5

Barışık, D., Tavman, Ş. (2018). Glütensiz ekmek formülasyonlarında nohut unu kullanımının ekmeğin kalitesi üzerine etkisi. *Akademik Gıda*, 16(1), 33–41. https://doi.org/10.24323/akademik-gida.415652

Benincasa, P., Falcinelli, B., Lutts, S., Stagnari, F., Galieni, A. (2019). Sprouted grains: A comprehensive review. *Nutrients*, 11(2), 421. https://doi.org/10.3390/nu11020421

Cansız, Z. (2018). Peynir Altı Suyunun Pastörizasyonu ve Ekmek Üretiminde Kullanım İmkanlarının Araştırılması (Thesis). Ankara University, Ankara.

Cevallos-Casals, B.A., Cisneros-Zevallos, L. (2010). Impact of germination on phenolic content and antioxidant activity of 13 edible seed species. *Food Chemistry*, 119(4), 1485–1490. https://doi.org/10.1016/j.foodchem.2009.09.030

Domínguez-Arispuro, D.M., Cuevas-Rodríguez, E.O., Milán-Carrillo, J., León-Lòpez, L., Gutièrrez-Dorado, R., Reyes-Moreno, C. (2018). Optimal germination condition impacts on the antioxidant activity and phenolic acids profile in pigmented desi chickpea (*Cicer arietinum L.*) seeds. *Journal of Food Science and Technology*, 55(2), 638–647. https://doi.org/10.1007/s13197-017-2973-1

Farooqui, A.S., Syed, H.M., Talpade, N.N., Sontakke, M.D., Ghatge, P.U. (2018). Influence of germination on chemical and nutritional properties of barley flour. *Journal of Pharmacognosy and Phytochemistry*, 7(2), 3855–3858.

Fayyaz, N., Mohebbi, M., Milani, E. (2018). Effect of germination on nutrients, mineral, phytic acid and enzyme activity of mung bean. *Acta Medica Mediterranea,* 34, 597.

Gadallah, M.G. (2017). Rheological, organoleptical and quality characteristics of gluten-free rice cakes formulated with sorghum and germinated chickpea flours. *Food Science & Nutrition*, 8(5), 535–550. https://doi.org/10.4236/fns.2017.85037

Gan, R.Y., Wang, M.F., Lui, W.Y., Wu, K., Corke, H. (2016). Dynamic changes in phytochemical composition and antioxidant capacity in green and black mung bean (*Vigna radiata*) sprouts. *International Journal of Food Science*, 51(9), 2090–2098. https://doi.org/10.1111/ijfs.13185

Hossain, M.T., Hossain, M.M., Sarker, M., Shuvo, A.N., Alam, M.M., Rahman, M.S. (2014). Development and quality evaluation of bread supplemented with jackfruit seed flour. *International Journal of Nutrition and Food Sciences*, 3(5), 484-487. https://doi.org/10.11648/j.ijnfs.20140305.28

Ikram, A., Saeed, F., Afzaal, M., Imran, A., Niaz, B., Tufail, T. (2021). Nutritional and end-use perspectives of sprouted grains: A comprehensive review. *Food Science & Nutrition*,9(8), 4617–4628. https://doi.org/10.1002/fsn3.2408

Islam, M.Z., An, H.G., Kang, S.J., Lee, Y.T. (2021). Physicochemical and bioactive properties of a high β-glucan barley variety 'Betaone' affected by germination processing. *International Journal of Biological Macromolecules*, 177, 129–134. https://doi.org/10.1016/j.ijbiomac.2021.02.053

Keregero, M.M., Mtebe, K. (1994). Acceptability of wheat-sorghum composite flour products: An assessment. *Plant Foods for Human Nutrition*, 46, 305–312. https://doi.org/10.1007/BF01088429

Kumari, N., Sindhu, S.C., Rani, V., Kumari, V. (2021). Shelf life evaluation of biscuits and cookies incorporating germinated pumpkin seed flour. International Journal of *Current Microbiology and Applied Sciences*, 10(01), 1436–1443. https://doi.org/10.20546/ijcmas.2021.1001.170

Lotfy, T.M.R., Agamy, N.F., Younes, N.M. (2021). The effect of germination in barely on its chemical composition, nutritional value and rheological properties. *Home Economics Research Journal*, 37(2), 81–108. https://doi.org/10.21608/jhe.2021.178699

Malik, I.O.M., Yousif, S.A., Ali, A.E., Hamadnalla, H.M.Y. (2021). Effect of germination on proximate composition of three grains from Sudan. *Journal of Nutrition & Food Sciences*, 3(5), 104–109. https://doi.org/10.22259/2637-5362.0501003

Miyahira, R.F., Lopes, J.O., Antunes, A. (2021). The use of sprouts to improve the nutritional value of food products: A brief review. *Plant Foods for Human Nutrition*, 76(2), 143–152. https://doi.org/10.1007/s11130-021-00888-6

Nkhata, S.G., Ayua, E., Kamau, E.H., Shingiro, J.B. (2018). Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. *Food Science & Nutrition*,6(8), 2446–2458. https://doi.org/10.1002/fsn3.846

Ognean, C.F. (2015). Technological and sensorial effects of sorghum addition at wheat bread. *Agriculture and Food*, 3(1), 209–217.

Paiva, C.L., Netto, D.A.M., Queiroz, V.A.V., Gloria, M.B.A. (2022). Germinated sorghum (*Sorghum bicolor L.*) and seedlings show expressive contents of putrescine. *LWTFood Science and Technology*, 161, 113367. https://doi.org/10.1016/j.lwt.2022.113367

Rani, M., Bandral, J.D., Sood, M., Sharma, S., Gupta, S., Chand, G. (2022). Effect of germination on physico-chemical and antinutritional factors of oats flour. *Pharma Innovation*,11(6), 1424–1428.

Riaz, A., Wahab, S., Hashmi, M.S., Shah, A.S. (2007). The influence of mungbean and mashbean supplementation on the nutritive value of whole wheat flour bread. *Sarhad Journal of Agriculture*, 23(3), 737.

Sibanda, T., Ncube, T., Ngoromani, N. (2015). Rheological properties and bread making quality of white grain sorghum-wheat flour composites. *International Journal of Food Sciences and Nutrition*, 5(4), 176–182.

Singleton, V.L., Rossi, J.A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American Journal of Enology and Viticulture*,16(3), 144–158.
https://doi.org/10.5344/ajev.1965.16.3.144

Tarasevičienė, Ž., Danilčenko, H., Jariene, E., Paulauskienė, A., Gajewski, M. (2009). Changes in some chemical components during germination of broccoli seeds. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 37(2), 173-176.

Tizazu, S., Urga, K., Belay, A., Abuye, C., Retta, N. (2011). Effect of germination on mineral bioavailability of sorghum-based complementary foods. *African Journal of Food, Agriculture, Nutrition and Development*, 11(5), 5083–5095.
https://doi.org/10.4314/ajfand.v11i5.70438

Tok, H., Ertas, N. (2021). The effects of germinated seeds on nutritional and technological properties of bread. *Journal of the Institute of Science and Technology*, 11(2), 1183-1193.
https://doi.org/10.21597/jist.820631

Warle, B.M., Riar, C.S., Gaikwad, S.S., Mane, V.A. (2015). Effect of germination nutritional quality of soybean (*Glycine max*). J*ournal of Environmental Science, Toxicology and Food Technology*, 9(4), 12-15.

Wongsiri, S., Ohshima, T., Duangmal, K. (2015). Chemical composition, amino acid profile and antioxidant activities of germinated mung beans (*Vigna radiata*). *Journal of Food Processing and Preservation*, 39(6), 1956–1964.
https://doi.org/10.1111/jfpp.12434

Xu, M., Jin, Z., Simsek, S., Hall, C., Rao, J., Chen, B. (2019). Effect of germination on the chemical composition, thermal, pasting, and moisture sorption properties of flours from chickpea, lentil, and yellow pea. *Food Chemistry*, 295, 579–587.
https://doi.org/10.1016/j.foodchem.2019.05.167

Zhu, D., Hettiarachchy, N.S., Horax, R., Chen, P. (2005). Isoflavone contents in germinated soybean seeds. *Plant Foods for Human Nutrition*, 60, 147–151.
https://doi.org/10.1007/s11130-005-6931-0