GLUTEN-FREE SOURDOUGH BREAD PREPARED WITH CHESTNUT AND RICE FLOUR

Ilkem Demirkesen Mert[1], Osvaldo H. Campanella[2,3], Gulum Sumnu[1], Serpil Sahin[1]

[1] *Department of Food Engineering, Engineering Faculty, Middle East Technical University, Universiteler Mah, Ankara, Turkey, e-mail: gulum@metu.edu.tr*

[2] *Department of Agricultural and Biological Engineering, Engineering Faculty, Purdue University, West Lafayette, IN, USA*

Abstract

In order to meet the rising demand of celiac patients for high quality and healthier products, the old biotechnological process, sourdough technology, was applied in gluten-free bread-making. In present study, the effect of addition of different amounts of sourdough (0%, 20% and 40%, % flour basis) on the rheological behaviour of the gluten-free chestnut-rice dough formulations prepared with chestnut and rice flours as well as on the quality parameters (pH, total titratable acidity (TTA), firmness and volume) of chestnut-rice breads was pointed out. The increasing levels of sourdough addition reduced pH and increased TTA values of samples. The addition of sourdough decreased complex modulus (G*) of dough samples showing softening of dough. The highest specific volume and the lowest firmness values were obtained from gluten-free breads with the addition of 20% sourdough. However, higher level (40%) of sourdough addition had detrimental effect on volume and firmness of breads. The results of present study showed that addition of 20% of sourdough can be used to improve the quality of gluten-free chestnut-rice breads.

Keywords: chestnut flour, gluten-free bread, rice flour, sourdough.

Introduction

Celiac disease, which is an autoimmune disorder, occurs in genetically vulnerable individuals by exposure to cereal gluten proteins. Since gluten creates a continuous protein network which helps to retain gas produced from yeast fermentation and oven rise, lots of the gluten-free baked products on the market are of poor quality with low volume, and poor texture. For these reasons, gluten replacement is still remaining to be one of the most trivial tasks for cereal technologist and scientists (Moore et al., 2008; Demirkesen et al., 2010). Sourdough, a mixture of flour and water fermented with lactic acid bacteria and/or yeast, are used to improve the quality of wheat breads (Moroni et al., 2009). In order to meet the rising demand of celiac patients for high quality and healthier products, this old biotechnological process has lately been applied as a new approach in gluten-free bread-making.

Chestnut flour contains high quality proteins with essential amino acids (4–7%), relatively high amount of sugar (20–32%), starch (50–60%), dietary fibre (4–10%), and low amount of fat (2–4%) (Demirkesen et al., 2010). It also includes some important vitamins such as vitamins E, C, B group and minerals such as potassium, phosphorous, magnesium, calcium, copper, iron, manganese and sulphur (Chenlo et al., 2007; Demirkesen et al., 2010). In addition, it has some important phenolics (gallic and ellagic acid) that have various positive health effects (Blaiotta et al., 2012). It has been stated that gluten-free breads prepared using chestnut-rice flour mixtures had higher volume and softer texture compared with those prepared with only chestnut or rice flour (Demirkesen et al., 2010; 2011; 2013a). In a recent study, it has also been observed that the staling of gluten-free rice breads was delayed by the partial replacement of rice flour with chestnut flour (Demirkesen et al., 2013b). The main objective of the present study was to investigate the effect of the addition of different amounts of sourdough (0%, 20% and 40%, % flour basis) on the rheological behaviour of gluten-free chestnut-rice dough formulations. In addition, the quality parameters (pH, total titratable acidity (TTA), firmness and volume) of chestnut-rice breads were determined.

Materials and Methods

Characterisation of ingredients

Chestnut flour was supplied by Kafkas Pasta Şekerleme San. & Tic. A.Ş. (Karacabey, Bursa, Turkey). Bob's Red Mill Organic Brown Rice Flour (Milwaukie, OR, USA) was obtained from a local market. Sugar (sucrose), salt, vegetable oil (MarketPantry® vegetable oil, MN, USA) and instant yeast (RedStarYeast & Products, Milwaukee, WI, USA) were purchased from local markets. A gluten-free commercial starter named brown rice sourdough starter (*L. plantarum*) specifically designed for use in gluten-free sourdough breads was used. Emulsifier DATEM (diacetyltartaric acid esters of monoglycerides) (E) was obtained from Danisco Co., (Copenhagen, Denmark). Xanthan (X) and guar (G) were obtained from Sigma–Aldrich (St. Louis, MO, USA).

Sourdough (SD) preparation

The starter stain (0.6 g) was added to water (100 g), rice flour (70 g) and chestnut flour (30 g) mixture thereby giving a dough yield of 200 (Table 1). The resultant dough was mixed thoroughly by hand for 2 min, poured into large beakers, covered and then incubated in proofer (InterMetro Industries Co., Wilkes-Barre, PA) at 30 °C and 85% relative humidity (RH) for 72 hours. Then, different amount of the sourdough (20% and 40% flour basis) was added to bread formulations.

Bread making procedure

Gluten-free bread formulations used in this study are presented in Table 1. Percentages of ingredients were based on 100 g of flour amount.

Table 1

Formulations used to prepare different gluten–free bread types containing different amount of sourdough

Ingredients (% flour basis)	Control	20% SD*	40% SD
Chestnut flour	30	24	18
Rice flour	70	56	42
SD	-	20	40
Water	163	143	123
Sugar	8	8	8
Salt	2	2	2
Oil	8	8	8
Yeast	2	2	2
X-G gum blend	0.5	0.5	0.5
** E	0.5	0.5	0.5

* SD – sourdough
** E – emulsifier DATEM

During dough preparation, dry ingredients (chestnut flour, rice flour, instant yeast, sugar, salt and emulsifier) were mixed thoroughly, and then the melted shortening was added. Finally gum suspension and water were added slowly and mixed for 3 min at 85 rpm and then 2 min at 140 rpm using a mixer (Kitchen Aid, 5K45SS, ELKGROVE Village, USA). After complete mixing, fermentation was done at 35 °C and 85% RH in a proofer (InterMetro Industries Co., Wilkes-Barre, USA) for 40 min. Following fermentation, gluten-free bread samples were baked in a rotatory electric oven (National Mfg. Co., Lincoln, USA) and breads samples (200 g each) were baked at 200 °C for 30 min. Gluten-free breads prepared with 30% of chestnut and 70% rice flour and without addition of sourdough were used as controls.

Rheological measurements

Dough samples for the rheological tests were prepared without adding any yeast to the formulation to avoid interference of bubble formation. The rheological measurements were conducted using a rheometer (ARG-2 Model, from TA Instruments, Newcastle, DE, USA) with a parallel plate geometry (40 mm diameter and 2 mm gap) at 25 °C. For the relaxation of the residual stresses, the dough was rested at room temperature for 20 minutes before testing. Frequency sweep experiments were carried out at 0.5% strain rate between 0.1 to 10 Hz. Results were expressed in terms of complex modulus (G*) values. All the rheological experiments were performed at least twice and their averages were reported in the study.

pH and TTA (total titratable acidity) in gluten-free sourdoughs and breads

The total titratable acidity (TTA) and pH values were determined in bread dough and breads. The pH values were measured from an aliquot of 10 g of sourdough, bread dough and bread crumb suspended with 100 mL distillated water. For the determination of TTA, these suspensions were titrated to against 0.1 N NaOH to a final pH valve of 8.5. TTA was expressed as the amount of 0.1 N NaOH 10 g^{-1} consumed in mL. Each analysis was done in triplicate and their averages were reported in the study.

Firmness

Baked loaves were allowed to cool for 1 h before obtaining measurements using the TA-XT2 Texture Analyzer (Texture Technologies Corp., Scarsdale, NY, USA). Samples in cubic shapes having dimensions of 25×25×25 mm were taken from the centre of bread and were compressed to 25% of its thickness with a cylindrical probe of diameter 25.4 mm (approved method 74–09, AACC 2000). The firmness, F (the force required to compress the sample) of the crumb was calculated from a force–distance graph. The measurements were done in duplicate.

Specific bulk volume

To determine specific volume, weight of loaves (g) was measured and bread volume (cm^3) was determined by the rapeseed displacement method 20 min after cooling at 25 °C. Then, specific volume was calculated as the volume/mass ratio (cm^3 g^{-1}) of bread according to (approved method 10–05, AACC 2000). The measurements were done in duplicate.

Statistical analysis

One-way ANOVA was used to determine whether gluten-free formulations affected firmness and specific volume of breads significantly ($p \leq 0.05$). If significant difference was found, means were compared by using the Tukey multiple comparison test ($p \leq 0.05$) by using MINITAB (Version 16) software.

Results and Discussion

pH and TTA of sourdough, dough and bread

Data on acidification of gluten-free bread dough and breads prepared with/without the addition of different amounts of sourdough was compared in Table 2. In the lack of sourdough, control dough and bread samples had the highest pH and the lowest TTA values. The increasing levels of sourdough addition reduced pH and increased TTA values of samples. The similar findings have been reported by Crowley et al., 2002 and Moroni et al., 2011.

Table 2

pH and TTA values of dough's and breads prepared with the addition of different amount of sourdough

Sample	Dough		Bread	
	pH	TTA	pH	TTA
Control	6.41±0.08	2.82±0.02	6.44±0.02	2.97±0.04
20% SD	5.32±0.21	5.41±0.01	5.42±0.06	5.23±0.07
40% SD	4.87±0.01	7.37±0.05	4.94±0.04	6.97±0.09

Rheological measurements

The complex modulus (G*) values of dough samples prepared with/without the addition of different amounts of sourdough can be seen in Figure 1.

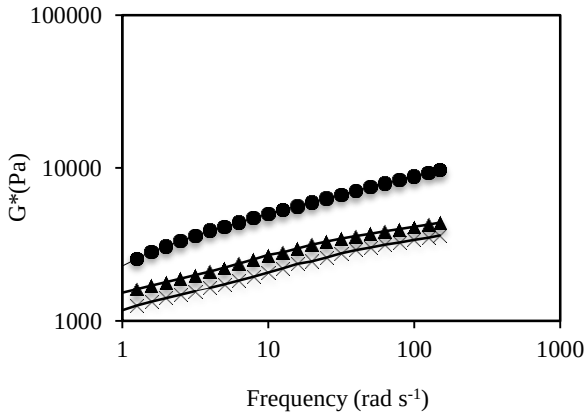

Figure 1. Complex modulus (G*) of gluten-free dough samples prepared with/without the addition of different amounts of sourdough

(●) – control chestnut-rice dough, (▲) –dough prepared with addition of 20% sourdough, (×) – dough prepared with addition of 40% sourdough

The highest complex modulus over the whole frequency range was obtained from control chestnut-rice dough samples. The addition of sourdough decreased complex modulus (G*) of dough samples. Further decreases in the complex modulus (G*) were observed with the addition of higher amount of sourdough (40%). The decreases in complex modulus (G*) of dough samples showed that the addition of sourdough promoted softening of dough. Protein breakdown and the consequent release of small polypeptide during fermentation have also been identified as the major cause for the weakening of the protein-protein and protein-starch interactions resulting in impairing of elasticity of dough (Houben et al., 2010). Consequently, the decreases of complex modulus in gluten-free dough samples might be related to reduced water holding capacity of hydrolyzed proteins, which was induced by organic acids and enzymes released during the sourdough fermentation. Thus, the lack of sourdough fermentation, higher complex modulus (G*) values were obtained as compared to control dough samples. Drastic decreases in the degree of elasticity of dough by sourdough fermentation were also shown in different studies (Clarke et al., 2002; Houben et al., 2010; Galle et al., 2012).

Firmness and specific volume of breads

Firmness and specific volume of breads prepared with/without the addition of different amount of sourdough can be seen in Fig. 2–3.

The addition of sourdough improved the texture of gluten-free breads, beyond a certain amount. Therefore, the lowest firmness values were obtained from breads with the addition of 20% sourdough.

Figure 2. Firmness values of gluten-free dough samples prepared with/without the addition of different amounts of sourdough

Control: control chestnut-rice bread, 20% SD: bread prepared with addition of 20% sourdough, 40% SD: bread prepared with addition of 40% sourdough.

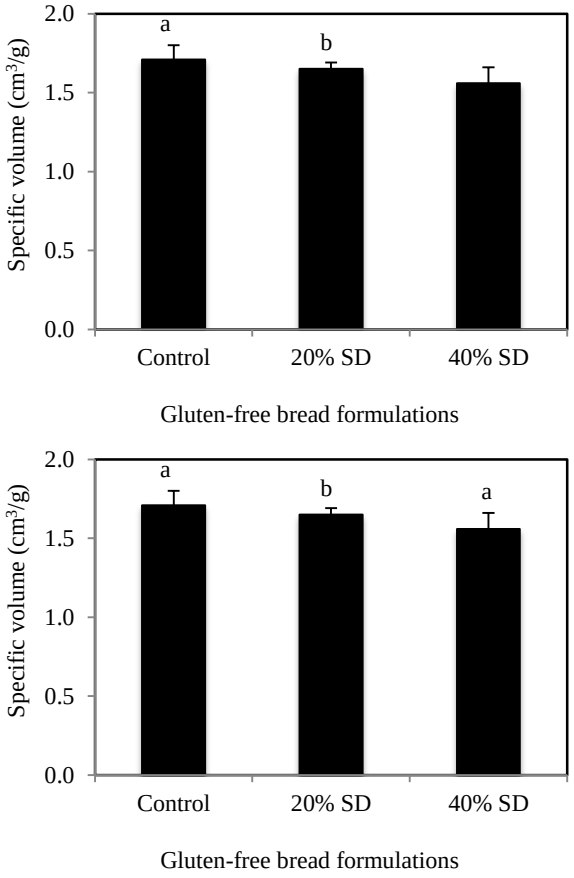

Figure 3. Specific volume values of gluten-free dough samples prepared with/without the addition of different amounts of sourdough

Control – control chestnut-rice bread, 20% SD – bread prepared with addition of 20% sourdough, 40% SD – bread prepared with addition of 40% sourdough.

The volume of gluten-free breads prepared with by the addition of 20% sourdough had comparable specific volume with control breads. However, further addition of sourdough deteriorated the quality of gluten-free

breads. Softer dough formation with the addition of sourdough might have facilitated greater bubble expansion upon fermentation process. Thus, the enhancement of specific volume and texture of gluten-free breads by the addition of certain amount of sourdough (20%) might be related to the improvement of the capacity of dough to retain CO_2. On the other hand, addition of higher level of sourdough (40%) had detrimental effect on volume and texture of breads since viscosity and viscoelastic properties of dough were not sufficient enough to allow bubble capture. Several previous studies also reported that sourdough addition might improve specific volume and texture of breads as long as it is used at certain amount (Crowley et al., 2002; Novotni et al., 2012).

Conclusion

Gluten-free breads formulated with the addition of different amounts of sourdough (0%, 20% and 40%) were evaluated using rheological and baking measurements. Rheological measurements showed that the addition of sourdough led to decreases in complex modulus (G*) of dough samples promoting softening of dough. According to baking tests, the breads prepared with the addition of 20% sourdough had the best quality parameters. However, higher level of sourdough addition led to some deterioration in quality parameters. Therefore, the results of the present study showed that the quality of gluten-free chestnut-rice breads can be successfully improved by the addition of 20% sourdough.

References

1. AACC (2000). Approved Methods of the American Association of Cereal Chemists (10th ed.) Methods 74–09, 10–05. The Association, St. Paul, Minnesota.
2. Blaiotta G., Di Capua M., Coppola R., Aponte M. (2012) Production of fermented chestnut purees by lactic acid bacteria. *International Journal of Food Microbiology*, Vol. 158, p. 195–202.
3. Chenlo F., Moreira R., Pereira G., Silva C. C. (2007) Evaluation of the rheological behaviour of chestnut (castanea sativa mill) flour pastes as function of water content and temperature. *Electronic Journal of Environmental Agriculture and Food Chemistry*, Vol. 6, p. 1794–1802.
4. Clarke C. I., Schober T. J., Arendt E. K. (2002) Effect of single strain and traditional mixed strain starter cultures on rheological properties of wheat dough and bread quality. *Cereal Chemistry*, Vol. 79, p. 640–647.
5. Crowley P., Schober T. J., Clarke C. I., Arendt E. K. (2002) The effect of storage time on textural and crumb grain characteristics of sourdough wheat bread. *European Food Research Technology*, Vol. 214, p. 489–496.
6. Demirkesen I., Campanella O. H., Sumnu G., Sahin, S., Hamaker, B. R. (2013b) A study on staling characteristics of gluten free breads prepared with chestnut and rice flours. *Food Bioprocess and Technology*, Vol. 7, p. 806–820.
7. Demirkesen I., Mert B., Sumnu G., Sahin S. (2010) Utilization of chestnut flour in gluten-free bread formulations. *Journal of Food Engineering*, Vol. 101, p. 329−336.
8. Demirkesen I., Sumnu G., Sahin S., Uysal N. (2011) Optimization of formulations and infrared-microwave combination baking conditions of chestnut-rice breads. I*nternational Journal of Food Science and Technology*, Vol. 46, p. 1809−1815.
9. Demirkesen I., Sumnu G., Sahin S. (2013a) Image analysis of gluten-free breads prepared with chestnut and rice flour and baked in different ovens. *Food Bioprocess and Technology*, Vol. 6, p. 1749–1758.
10. Galle S., Schwab C., Dal Bello F., Coffey A., Ganze M. G., Arendt E. K. (2012) Influence of in-situ synthetized exopolysaccharides on the quality of gluten-free sorghum sourdough bread. *International Journal of Food Microbiology*, Vol. 155, p. 105–112.
11. Houben A., Götz H., Mitzscherling M., Becker T (2010) Modification of the rheological behavior of amaranth (Amaranthushypochonriacus) dough. *Journal of Cereal Science*, Vol. 51, p. 350–256.
12. Moore M. M, Dal Bello F., Arendt E. K. (2008) Sourdough fermented by Lactobacillus plantarum FST 1.7 improves the quality and shelf life of gluten-free bread. *European Food Research Technology*, Vol. 226, p. 1309–1316.
13. Moroni A. V. Dal Bello F., Arendt E. K. (2009) Sourdough in gluten-free bread-making: An ancient technology to solve a novel issue? *Food Microbiology*, Vol. 26, p. 676–684.
14. Novotni D., Cukelj N., Smerdel B., Bituh M., Dujmic F., Curic D. (2012) Glycemic index and firming kinetics of partially baked frozen gluten-free bread with sourdough. *Journal of Cereal Science*, Vol. 55, p. 120–125.