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Effect of quinoa flour on gluten-free bread batter rheology and bread quality

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ABSTRACT

A new gluten-free bread formulations composed of quinoa, buckwheat, rice flour and potato starch were developed in the present study. Rheological characteristics of the bread batter with increasing amount of quinoa were determined; storage (G′) and loss modulus (G″) values were also measured for investigation of viscoelastic properties. To evaluate the quality of breads; technological and physical (bake loss %, specific volume, texture, microstructure, color), chemical (protein, moisture, ash) and sensory properties were determined. All batter formulations independent of the quinoa amount exhibited pseudoplastic behavior, and G′ values were found to be higher than G″ values in expressing the solid like characteristics of the batter. Amount of quinoa flour addition did not present significant difference on bake loss%, specific volume and protein content ($p>0.05$); however, 25% quinoa flour bread displayed better results with its higher sensory scores and softer texture. Quinoa and buckwheat flour mixture therefore will be a good alternative for conventional gluten-free bread formulations.

1. Introduction

Prolamins in wheat, rye and barley are major sources for creating digestive problems in people with celiac disease (Capriles and Arêas, 2014). Nowadays, the treatment of this disease is only possible by avoiding gluten in the daily diet. Gluten sensitivity represents the majority of food intolerance (Capriles and Arêas, 2014), and the production of bread without gluten, is therefore essential. There are many conventional gluten-free bread recipes; however, the current technology of gluten-free bakery products is based only on starches from different botanical origins, such as corn and rice (Pruska-Kedzior et al., 2008). Unfortunately, those gluten-free products often have poor quality; lower loaf volume, poor texture (chalky and crumbly) and poor mouthfeel due to the lack of gluten elasticity and low nutritional value. Quality and shelf life of gluten-free breads can be improved by using pseudo-cereals such as quinoa, buckwheat and amaranth with their nutritional value and the techno-functional properties (Torbica et al., 2010; Wronkowska et al., 2013; Capriles and Arêas, 2014).

Quinoa (*Chenopodium quinoa*) is an endemic crop of the Andean region (Stikic et al., 2012; Nascimento et al., 2014; Iglesias-Puig et al., 2015). It has been recognized as a very nutritious grain, due to the good quality and quantity of its protein and essential fatty acids (Hager, 2013). Essential amino acid content has also been found to be higher than that of wheat flour (Stikic et al., 2012); especially, lysine (a limiting amino acid for cereals) was found to be twice higher than wheat flour. According to the USDA nutrient database (2014), quinoa consists of 14.12% protein, 6.07% total lipid (fat), 64.16% carbohydrate and 7% dietary fiber. NASA declared that quinoa is an excellent crop with its good nutritional balance and that it can be used during long term human space missions (Schlick and Bubenheim, 1993). Clinical studies about the consumption of quinoa have indicated that childhood malnutrition and risk of cardiovascular diseases (by lowering triglycerides, LDL and cholesterol) may be reduced and help to modulate metabolic parameters (postmenopausal symptoms) in women with excess weight (Graf et al., 2015). In addition to good nutritional composition, quinoa does not contain any gluten, which has brought a new perspective to gluten-free bakery products.

Buckwheat (*Fagopyrum esculentum*) is another pseudo-cereal

Abbreviations: a, (+a: redness and −a: greenness); b, (+b: yellowness and −b: blueness); G′, storage modulus; G″, loss modulus; K, consistency index (Pa.s^n); L, brightness (0: black, 100: white); n, power-law index; R^2, coefficient of determination; RMSE, root mean square error; γ, shear rate (s^{-1}); η_0, plastic viscosity (Pa.s); τ, shear stress (Pa); τ_0, yield stress (Pa).

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crop that attracts attention with its nutritional composition, since it contains 13.25% protein, 3.4% total lipid (fat), 71.50% carbohydrate, and 10% dietary fiber (USDA, 2014), as well as essential vitamins and minerals (Bilgiçli and İbanoğlu, 2015). Studies have shown that antioxidant capacity and amount of aroma compounds were improved in buckwheat bread compared to wheat flour bread (Lin et al., 2008). Replacement of wheat flour with an increasing amount of buckwheat flour also increased the mineral content of breads; Cu, Fe, K, Mg, Mn, P and Zn were statistically higher than in the control sample (Bilgiçli and İbanoğlu, 2015).

The aim of this study was to develop a new gluten-free bread formulation from different amounts of quinoa and buckwheat flour incorporated into rice flour and potato starch mixture. The effects of quinoa and buckwheat flour were evaluated by means of rheological properties of bread batter as well as technological, physical, and sensory properties of gluten-free breads.

2. Materials and methods

2.1. Materials

Whole quinoa seed was purchased from Bora Tarim Urunleri Gida San. Tic. Ltd. (Istanbul, Turkey). Buckwheat seeds (Degirmen Tic., Izmir, Turkey), rice flour (Kenton, Ankara, Turkey), potato starch, sugar, salt, sunflower oil, compressed yeast (Pakmaya, Izmir, Turkey) and xanthan gum (Sigma–Aldrich) were purchased from local markets in Izmir. Quinoa and buckwheat seeds were ground in a lab scale hammer mill (Armfield, UK), and then subjected to sieving. Flours having a diameter lower than 0.5 mm were used in the experiments.

2.2. Methods

2.2.1. Preparation of breads

Gluten-free bread formulations are given in Table 1A. The formulation was developed according to the study of Alvarez-Jubete et al. (2010) with some major modifications: rice flour and potato starch were kept constant at 50% of the total flour and starch mixture, and buckwheat flour was replaced with increasing amounts of quinoa flour.

The control bread (C) was composed of only buckwheat flour, rice flour and potato starch. The amount of water used in the formulations was kept constant at 87% (on flour mixture basis) as recommended in the study of Alvarez-Jubete et al. (2010) and the structure of obtained mixtures were like a thick batter rather than dough.

For the batter preparation, all ingredients except xanthan gum were mixed thoroughly for 10 min at low speed in a spiral mixer (Kitchen Aid 5k45 Mixer, USA). After the addition of xanthan gum, the batter was mixed for another 5 min at high speed. The batter was then divided into 400 g portions and poured into Teflon-coated baking pans. Finally, it was fermented in the fermentation chamber (Inoksan FGM 100, Turkey) at 35 °C and 85% RH for 30 min. Following the fermentation step, the samples were baked at 200 °C and 50% RH for 50 min in a convection oven (Inoksan FBE 010, Turkey). The bread was removed from the pans immediately after baking and cooled at room temperature (25 °C) for at least 6 h before the analyses.

Table 1
Bread formulations, flour composition, flour and bread properties, A: Gluten-free bread formulations for 100 g of total flour + starch basis; B: composition and water absorption capacities of flours; C: baking properties of gluten-free breads.

A

Ingredients (On flour + starch %)	C	Q1	Q2	Q3	Q4
Rice flour	25	25	25	25	25
Potato starch	25	25	25	25	25
Quinoa flour	–	12.5	25	37.5	50
Buckwheat flour	50	37.5	25	12.5	–
Salt	2	2	2	2	2
Sugar	3	3	3	3	3
Oil	6	6	6	6	6
Yeast	3	3	3	3	3
Xanthan gum	0.5	0.5	0.5	0.5	0.5
Water	87	87	87	87	87

B

Flour type	Moisture (%)	Ash[1] (%)	Protein[1] (%)	SDF[1] (%)	IDF[1] (%)	TDF[1] (%)	Water absorption capacity (%)
Quinoa	9.13[a]	2.35[b]	15.54[c]	2.09[b]	14.39[b]	16.48[c]	119.87[c]
Buckwheat	9.95[a]	2.21[b]	14.72[b]	1.74[a]	10.84[b]	12.58[b]	102.67[b]
Rice	16.07[c]	0.55[a]	7.07[a]	1.49[a]	3.39[a]	4.85[a]	146.16[d]
Potato starch	11.22[b]	0.51[a]	–	–	–	–	67.79[a]

C

Sample code	Bake loss (%)	Specific volume (cm^3/g)	Moisture (%)	Protein[1] (%)	Ash[1] (%)	Water activity
C	14.4[a]	1.87[a]	47.5[c]	7.65[a]	1.68[a]	0.940[c]
Q1	15.4[a]	1.85[a]	44.3[b]	7.81[a]	1.36[a]	0.930[c]
Q2	15.1[a]	1.76[a]	44.4[b]	8.40[a]	2.33[a]	0.930[c]
Q3	15.1[a]	1.78[a]	41.2[a]	8.17[a]	2.16[a]	0.925[a,b]
Q4	15.4[a]	1.73[a]	40.9[a]	8.18[a]	2.06[a]	0.910[a]

[a–d] Different letters in the same column indicate significant differences between means ($p < 0.05$).
[1] On dry basis.

2.3. Rheological measurements

Rheological measurements were conducted using a DHR3 rheometer (TA Instruments, USA). Bread batter were prepared according to the formulations given in Table 1A without adding any yeast to the formulations as recommended in the study of Demirkesen et al. (2010a). All measurements were conducted at 25 °C, using parallel plate geometry (40 mm diameter, with 1 mm gap). Amplitude sweep analyses were carried out between 10^{-3}–10^{2}% strain to determine linear viscoelastic region of the batter samples. The amplitude sweep test results showed that all bread batter formulations showed a linear region between 0.1 and 10%; therefore, 0.1% strain was selected for frequency sweep tests for determining differences between samples. Frequency sweep experiments were carried out between a frequency of 0.1–10 Hz, and storage (G′) and loss modulus (G″) versus frequency values were recorded. Flow ramp tests were conducted at shear rate between 0.01 and 50 s^{-1} under steady shear conditions. Bread batter formulations were prepared in two parallels, the rheological experiments were performed in triplicate, and their averages are reported in this study.

2.4. Analysis of flour samples

Water absorption capacity and protein content of flour samples were measured according to AACC method no 56-11 and 46-12, respectively (AACC, 2010). Moisture (ICC, 1996), and ash contents (ICC, 1996) of the flour were determined using ICC standard methods. Soluble and insoluble dietary fiber content of the flours was determined by using AOAC method no 991.43 (AOAC, 1998).