LWT - Food Science and Technology 63 (2015) 1121–1127

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Development of gluten-free wafer sheet formulations

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ARTICLE INFO

Article history:
Received 20 November 2014
Received in revised form
10 April 2015
Accepted 13 April 2015
Available online 25 April 2015

Keywords:
Buckwheat flour
Chestnut flour
Corn flour
Rice flour
Wafer sheet

Chemical compounds studied in this article:
Salt (PubChem CID: 5234)
Sodium bicarbonate (PubChem CID: 516892)

ABSTRACT

The main objective of this study was to develop gluten-free wafer sheet formulations by replacing rice flour partially with different gluten-free flours at different ratios. Rice-corn flour blends, rice-buckwheat flour blends and rice-chestnut flour blends with different ratios (80:20, 60:40, 40:60) were used in the experiments in order to find the higher quality and more nutritional gluten-free wafer sheet formulations. As a control, wafer sheet samples containing only rice flour and only wheat flour were used. Rheological properties of batters and color and texture of wafer sheets were determined. In the rheological analyses, it was observed that Power law model was suitable to explain the flow behavior of all samples. Among these samples rice and buckwheat flour containing sample at a ratio of 60:40 had the closest value of consistency and flow behavior index to wheat flour containing sample. In texture analyses, samples containing only rice flour and all the samples with corn flours had harder texture compared to the other samples. In the color analyses of wafer sheets, the effects of natural color of the flours were clearly observed.

1. Introduction

Celiac disease, a disease caused by an immune disorder which is also known as gluten sensitive enteropathy, occurs in people who have a genetic problem with consumption of gluten (Cureton & Fasano, 2009). The only known cure for celiac disease is to avoid consumption of gluten containing products (Mendoza, 2005). However, the absence of gluten affects dough or batter rheology, production process and the quality of gluten free product (Houben, Höchstötter, & Becker, 2012). Therefore, gluten free products have low volume and poor texture and flavor (Demirkesen, Sumnu, & Sahin, 2013). In addition, gluten free baked products do not contain sufficient amounts of vitamins, minerals and fiber. Rice flour is commonly used in gluten-free baked products due to its low levels of sodium, protein, fat and a high amount of easily digested carbohydrates. Despite of its numerous advantages, rice proteins have poor functional properties. The hydrophobic nature of rice proteins prevents the formation of viscoelastic structure in dough (Rosell & Collar, 2007). Moreover, rice flour does not contain sufficient amounts of vitamin, minerals and fiber which is important for balanced diet of celiac patients. For this reason, rice flour should be combined with other flours such as corn, chestnut, chickpea, soybean, sorghum, buckwheat, quinoa and amaranth flour to give the structure in gluten free baked products.

Chestnut flour is a good alternative flour to be used in gluten free baked products since it contains high quality proteins with essential amino acids (4–7 g/100 g), relatively high amount of sugar (20–32 g/100 g), starch (50–60 g/100 g), dietary fiber (4–10 g/100 g), and low amount of fat (2–3 g/100 g). Another advantage of using chestnut flour is that it is rich in vitamin E, Vitamin B group, potassium, phosphorous, and magnesium (Demirkesen, Mert, Sumnu, & Sahin, 2010a). Buckwheat flour is a good source of minerals (sodium, iron, calcium, magnesium, potassium, manganese, copper and zinc) as compared to wheat and rice flour (Wei, Zhang & Li., 1995). Moreover, buckwheat flour contains high amount of fiber as compared to rice and corn flour so their use in gluten free products help to increase fiber intake in celiac patients (Saturni, Ferretti, & Bacchetti, 2010).

In recent years, gluten-free foods, especially breads, cakes and biscuits have been commonly investigated by many researchers. Numerous studies have been conducted especially on gluten-free bread. The rheological properties of rice flour containing gluten-free bread dough were examined by Demirkesen, Mert, Sumnu, and Sahin (2010b). Their measurements showed that in order to

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http://dx.doi.org/10.1016/j.lwt.2015.04.035
0023-6438/

get the desired physical properties in dough formulation, addition of emulsifiers and gums were necessary. Gluten free bread production by substituting rice flour with carob flour and resistant starch was found to be a promising approach in producing fiber-rich formulations (Tsatsaragkou, Gounaropoulos, & Mandala, 2014). Torbica, Hadnadev, and Dapcevic (2010) showed that combining rice flour with buckwheat flour in gluten free breads did not require addition of hydrocolloids for the development of dough structure. Wronkowska, Haros, and Soral-Smietana (2013) showed that using buckwheat flour had a positive effect in gluten free bread in terms of improving texture and delaying staling of breads. Demirkesen et al. (2010a) showed that addition of chestnut flour improved functional and technological properties of dough as well as the color and flavor properties of breads.

There are also studies about other types of gluten-free products in addition to bread. Macro and micro-structures of rice cakes prepared with different kinds of gums and baked in different ovens were examined by Turabi, Sumnu, and Sahin (2010) quantitatively. It was found that the usage of xanthan and xanthan–guar gum blend resulted in more porous cakes. Schober, O'Brien, McCarthy, Darnedde, and Arendt (2003) evaluated the effects of fat powders and combinations of gluten-free flour on quality of biscuits. They found that biscuits formulated with rice-corn-potato-soya flour blend at a ratio of 70:10:10:10 was similar to biscuits formulated with wheat flour in terms of water activity, moisture, texture, diameter, thickness and color.

It is important to choose the suitable flour to produce high quality wafers. Wheat flour is known to provide structure to wafer (Tiefenbacher, 2002). There is an optimum amount of gluten that affects wafer quality. In other words less gluten will make it weak and fragile but too much gluten will make it hard. Using only rice flour in gluten free wafers is expected to result in poor quality and low nutritional value. There is no study on gluten-free wafers in literature. Therefore, the main objective of this study was to develop gluten-free wafer sheet formulations by combining rice flour with corn, buckwheat and chestnut flour so that quality of gluten free wafer sheets will be similar to wheat flour containing wafer sheets. In addition, it was aimed to determine the effects of different gluten-free flours in different ratios on rheological properties of wafer batter and color and texture of wafer sheets which are important quality parameters in acceptability of wafer sheets. Since corn, buckwheat and chestnut flours are rich in essential amino acids and minerals, these flours can meet the nutritional requirements of celiac patients. Using different gluten-free flours will also contribute to variety of celiac patients' diets.

2. Experimental

2.1. Materials

For wafer sheet batter preparation, rice flour (Gamsan Gıda İmalat San. ve Dış Tic. Ltd. Şti., Istanbul, Turkey) having 14 g/100 g moisture, 6 g/100 g protein (N $\times$ 5.95), 0.75 g/100 g ash, wheat flour having 14.5 g/100 g moisture, 7 g/100 g protein, 0.55 g/100 g ash, water (Kalabak, Eskişehir, Turkey), salt, sodium bicarbonate, coconut oil and sunflower lecithin were obtained from Eti Food Industry and Co. Inc. (Eskişehir, Turkey). Corn flour (Bağdat Baharat, Ankara, Turkey) with 10 g/100 g moisture, 8.84 g/100 g protein, 1.7 g/100 g ash, 33.48 g/100 g starch, 1.22 g/100 g sugar, 0.72 g/100 g fat and 5.99 g/100 g dietary fiber and buckwheat flour (Ekoloji Market, Istanbul, Turkey) having 10 g/100 g moisture, 11 g/100 g protein, 1.64 g/100 g ash, 2.77 g/100 g fat, 67.38 g/100 g starch, 6.5 g/100 g fiber were bought from local markets. Chestnut flour with 10.8 g/100 g moisture, 4.6 g/100 g protein, 47.8 g/100 g starch, 21.5 g/100 g sugar, 3.8 g/100 g fat, 9.5 g/100 g fiber and 2 g/100 g ash was supplied by Kafkas Pasta Şekerleme San.&Tic. A.Ş. (Karacabey, Bursa, Turkey).

2.2. Batter preparation

Wafer sheet containing only rice flour was used as a control since it is commonly used flour in gluten-free product development. As another control, wheat flour wafer sheet was prepared to compare the quality of gluten-free formulations with that of gluten containing one. In rice flour containing batter, 20, 40, 60 g/100 g of rice flour was replaced by corn, buckwheat or chestnut flours to obtain gluten-free wafer sheets.

In all the formulations, the batters were composed of 100 g flour or flour blends, 0.5 g salt/100 g flour, 0.4 g sodium bicarbonate/100 g flour, 1 g coconut oil/100 g flour and 0.5 g lecithin/100 g flour. The amount of water used in each batter formulation was different. They were adjusted depending on the time of flow of batter which is directly proportional to viscosity. In all samples the amount of water added to provide the time of flow to be 21 $\pm$ 1 s was determined by flow cup viscometer with 100 ml capacity (TQC, Capelle aan den Ijssel, The Netherlands).

During preparation of the wafer sheet batter, firstly, water was added into a laboratory type wafer mixer with a 5 L capacity (Hobart Corporation, Troy, Ohio, USA). Salt and sodium bicarbonate were fully dispersed in water for 10 s. Then, flour or flour blends were added to the mixture. Finally, blend of coconut oil and lecithin were added and final mixture was mixed for 4 min with mixer. The batter temperature was kept constant at 22 $\pm$ 1 °C throughout the experiments.

2.3. Baking

Before baking, the batter was held at room temperature for 10 min to allow air bubbles to rise to the top. This aeration process is important to prevent change in batter density during production which affects final weight of the product. Samples were baked using laboratory type wafer baking machine with dimensions of 290 mm $\times$ 210 mm $\times$ 5 mm (Franz HAAS, Vienna, Austria). According to the study of Dogan (2006), baking temperature above 170 °C increases product fragility and gives a dark color. Therefore, the temperature of the upper and lower plates was kept constant at 165 °C. Before baking release agent based on vegetable oil (Carlex spray, Zeelandia, Zierikzee, Holland) was used before pouring 125 $\pm$ 3 g portion of the batter on the center of the surface of the lower plate. Then, the upper plate was closed and lid was locked. Baking was continued until the final moisture content of wafer sheet reached to 1–2 g/100 g. Moisture content of the wafer sheet was measured by moisture analyzer (Sartorius, Goettingen, Germany). In all measurements, 3 g of samples taken from the center of the wafer sheets were used.

2.4. Rheological analyses of wafer sheet batter

The rheological measurements were conducted using Malvern rheometer (Kinexus, Worcestershire, UK). All measurements were done at 22 °C, using cone and plate geometry (40 mm diameter and 4° cone angle). The batter samples were placed between the plates and the edges were carefully trimmed with a spatula. The rheological measurements were conducted under steady-shear conditions with shear rate ranging from 20 to 200 1/s. For the relaxation of the residual stresses, the batter was rested at room temperature for 10 min before testing. Throughout the experiments, shear rate versus shear stress and shear rate versus apparent viscosity data were collected. It was investigated whether shear stress (τ) versus shear rate (γ) data obeys Power Law model (Equation (1)) or not;