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Gluten-free frozen dough: Influence of freezing on dough rheological properties and bread quality

S. Mezaize, S. Chevallier, A. Le-Bail, M. de Lamballerie *

Oniris, GEPEA (UMR CNRS 6144), BP 82225, 44322 Nantes cedex 3, France

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The freezing process at different steps of breadmaking is widely used to improve fresh bread availability for the consumer. The consequences of a freezing step on wheat dough and bread, and the way to reduce its negative impacts have been studied for years. Nevertheless, few works report studies on gluten-free doughs and breads. This work investigates the effect of unfermented frozen dough process on the properties of gluten-free dough and the quality of bread. Rheological oscillation tests showed that viscoelastic properties were unchanged for fresh and thawed doughs. However flow tests exhibit an effect of freezing on consistency index and flow behaviour index. Regarding the quality of bread, gluten-free breads obtained by frozen dough process had lower specific volumes and harder crumbs than conventional gluten-free breads (unfrozen breads). Distribution of gas cells was more homogeneous with a freezing step. Crust colour characteristics were also modified by the freezing step.

1. Introduction

Coeliac disease (CD) is a pathology affecting the upper small intestine mucosa due to an inappropriate immune response to gluten protein fractions (Marsh, 1992), which are mainly present in wheat, barley and rye. Patients with CD suffer from symptoms such as diarrhoea, weight loss, and iron, folate or vitamins B12 and D deficiencies (Woodward, 2007). In Europe and the United States, the prevalence of CD is estimated at 1 for 100–200 inhabitants (Cook et al., 2000; Hill et al., 2000). A strict gluten-free diet for life is the only treatment for CD patients, to date, despite considerable scientific advances in understanding CD and in preventing or curing its manifestations (Niewinsky, 2008). Thus, research projects and industrial products developments and more precisely gluten-free breads have been investigated for more than 40 years and show currently a rapid growth. Gluten-free breads formulation researches concern mainly gluten-free flours or starches (Mariotti, Lucisano, Pagani, & Ng, 2009; Sciarini, Ribotta, León, & Perez, 2008), hydrocolloids (Lazaridou, Duta, Papageorgiou, Belc, & Biliaderis, 2007), protein sources (Marco & Rosell, 2008a,b), enzymes (Gujral & Rosell, 2004; Renzetti, Dal Bello, & Arendt, 2008), sourdough (Sterr, Weiss, & Schmidt, 2009), dietary fibers (Korus, Grzelak, Achremowicz, & Sabat, 2006) and minerals (Kiskini et al., 2007).

Gluten proteins play a key role in the unique baking quality of wheat. Due to the presence of gluten network, wheat dough is characterized by unique viscoelastic properties, allowing the dough to retain gas produced mainly during the fermentation step. Thus, by using gluten-free ingredients, the gluten-free breads available on the market present poor organoleptic quality, not comparable to wheat ones: breads are compact and tasteless, with a light crust which merges with a crumbling crumb (Gallagher, Gormley, & Arendt, 2004). Moreover, gluten-free breads exhibit faster rate of staling when compared to wheat breads (Kadan, Robinson, Thibodeaux, & Pepperman, 2001). Shelf-life of these breads is a serious task and therefore represents a quality criterion in studies aiming at improving gluten-free bread formulations (McCarthy, Gallagher, Gormley, Schober, & Arendt, 2005; Sciarini et al., 2008; Onyango, Unbehend, & Lindhauer, 2009).

An alternative to get fresh gluten-free breads could be to insert a freezing step during the breadmaking process. It has been used for long in wheat breadmaking. Food industry uses a freezing process to delay some breadmaking steps and to make available fresh bread in retail stores, after baking, or to make available a frozen product that the consumer can bake at home when he needs it. Nevertheless, the freezing process causes physical and chemical damages in the product (dough, part baked bread or bread). Such a treatment on dough can cause dough weakening, a decrease in gas retention capacity and a reduced yeast activity (Inoue, Sapirstein, & Bushuk, 1995; Inoue & Bushuk, 1991; Angioloni, Balestra, Pinnavaia, & Dalla Rosa, 2008). These damages are responsible for defects in bread quality, such as a decrease in bread specific volume, an increase in crumb hardness and in crust flaking (Giannou & Tzia, 2007). The freezing implementation and the wheat bread formulas development have been the subject of numerous researches in order to understand the impact of freezing and to limit it on bread quality. In the present study, the freezing

* Corresponding author.
E-mail address: marie.de-lamballerie@oniris-nantes.fr (M. de Lamballerie).

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process was applied to a gluten-free dough in order to study impact of freezing on dough rheological properties and on gluten-free bread quality.

2. Materials and methods

2.1. Breadmaking

The same basic formulation was used for the conventional gluten-free bread making (abbreviated CV) and the frozen gluten-free dough bread making (abbreviated FD). The formulation used comes from a previous study (Mezaize, Chevallier, Le-Bail, & de Lamballerie, 2009). The formulation is shown in Table 1. Rice flour and corn flour were provided by Livrac (Haute-Goulaine, France) and buckwheat flour by Bio Moulin (Boussay, France). Potato starch came from KMC (Brande, Denmark) and corn starch from Tate and Lyle (Aaist, Belgium). Compressed yeast, salt and sunflower oil were obtained from local commercial sources (Nantes, France). Inulin was provided by Puratos (Groot-Bijgaarden, Belgium) and guar gum by Danisco (Zaandam, The Netherlands).

Flours, starches, inulin, guar gum and salt were blended at speed 1 (46 rpm) for 10 s in a mixer (Kitchenaid, St Joseph, MI, USA). Compressed yeast was incorporated and the ingredients were blended again at speed 1 for 10 s. Sunflower oil and tap water (at 20 °C) were added and all ingredients were mixed at speed 2 (82 rpm) for 2 min. Dough pieces (60 g) were weighed and placed in individual silicon muffin-like pans (40 mm height; 75 mm top diameter; 55 mm bottom diameter). In the conventional breadmaking, dough pieces were proofed for 50 min in a fermentation cabinet (Hengel, Le Coteau, France) at 40 °C and 95% humidity. Then breads were baked (oven condo Miwe, Arnstein, Germany) at 200 °C for 40 min with 0.5 L of steam at the start of baking. Breads were cooled at room temperature for 1 h and then placed in sealed plastic bags at room temperature for 1 h before analysis. In the frozen dough breadmaking, dough pieces were frozen in sealed plastic bag in a blast freezer cabinet at −30 °C for 30 min and were stored 7 days at −18 °C. Then, they were thawed at room temperature for 1 h, before being proofed without sealed bags. Proofing, baking and cooling steps were carried out exactly in the same conditions than for conventional breadmaking. Breadmaking was duplicated for each process tested.

2.2. Dough temperature recording

Core temperature and surface temperature of the dough pieces were recorded throughout the breadmaking process, from the end of mixing to the end of cooling, for the conventional breadmaking and for the frozen dough breadmaking. K type thermocouples, adapted on muffin-like pans and connected to a data logger (SA32 AOIP, Ris Orangis, France) measured temperature with an acquisition frequency of 15 s. For core temperature recording, the thermocouple (0.13 mm diameter) was maintained in a vertical position thanks to a small cylinder attached to the pan base and allow to measure temperature in the centre of the dough. For surface temperature recording, the thermocouple (0.08 mm diameter) extremity was delicately positioned on the dough surface.

Table 1
Gluten-free bread recipe.

Ingredients	Quantity (%)
Rice flour	22.8
Corn flour	7.2
Buckwheat flour	2.5
Corn starch	14.7
Potato starch	2.1
Inulin	1.2
Guar gum	0.9
Salt	0.8
Compressed yeast	2.6
Sunflower oil	3.0
Water	42.2

2.3. Bread characteristics

Breads from the two breadmaking processes were evaluated for their dry matter content, specific volume, crumb characteristics (hardness and gas cells size distribution) and crust colour. Specific volume was measured on 3 breads using a laser volumeter (Texvol Instruments, Villeuneuve-la-Garenne, France). For dry matter determination, 3 g of crushed bread was weighed into aluminum dishes and dried for 24 h in an oven (Memmert, Schwabach, Germany) at 103 °C. Five replicates were carried out. Crumb characteristics were assessed using a universal testing machine (Lloyd Instruments LR5K, Southampton, UK). A compression test with a cylindrical probe (20 mm diameter) was performed. 15 mm-thick slices were cut from the middle of the bread using an electric slicer (Graef, Arnsberg, Germany). Crumb was compressed to 40% of its initial height at 5 $mm.s^{-1}$. Tests were performed on 2 slices from 4 different breads. Images of sliced breads were captured using a flatbed scanner (HP, Palo Alto, USA) in grey levels at 350 dpi. A specific macro developed for bread gas cells identification, with Image J software (NIH, USA), was applied on these images, including the application of several filters to enhance the contrast between cells and cell walls and an automatic thresholding based on the *k*-means algorithm. From the area of each gas cell, the equivalent diameter (in surface) was calculated. Thus, the mean diameter of each slice for each type of breadmaking could be calculated. The dispersion of the gas cell diameter distribution was estimated by the variance of all cells equivalent diameter. Crust color was measured on the top surface of 4 breads using a Minolta chromameter (Minolta CR 400, Osaka, Japan). Lightness L^*, saturation C^* and hue h were recorded.

2.4. Dough fundamental rheology

Rheological measurements were performed on a controlled stress rheometer AR 1000 (TA Instruments, Guyancourt, France), fitted with parallel plate geometry consisting of a 40 mm diameter serrated flat plate. Samples of fresh dough or thawed dough were prepared as previously described for the breadmaking but without yeast. Dough was placed between the parallel plates. The gap was adjusted to 1 mm and the dough excess was trimmed of very carefully. The system was covered by paraffin oil to coat the outer edges to prevent the sample from drying. The dough was allowed to rest for 5 min so that the residual stress could relax. Two types of test were carried out: oscillation test and flow test. First, a frequency sweep from 0.1 and 100 Hz was performed at a constant strain of 0.1% at 20 °C. Preliminary strain sweep at 1 Hz indicated that 0.1% was included in the linear viscoelastic region. The dough structure was evaluated by comparison of log–log plots of G' and G'' with frequency. Results of frequency sweeps test are the average of three measurements. In the second test, a steady state flow was performed at shear rates from 0.02 s^{-1} to 10 s^{-1}. Each experimental point was reached within an established time of 1 min. Steady state flow curves were obtained for different temperatures: temperature was maintained constant during the test at 20, 30, 40, 50 or 60 °C. Apparent viscosity is reported as the mean of three replicates. The flow behaviour of dough was evaluated by comparison of log–log plots of apparent viscosity η_{app} with shear rate $\dot{\gamma}$. The curves were fitted with the power law equation (Eq. (1)):

$$\eta_{app} = K\dot{\gamma}^{n-1} \tag{1}$$

where K (Pa s^n) is the consistency index and n (dimensionless) the flow behaviour index. Power law model was chosen among several models, as it fits the best to our data.