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Thermo-physical and thermo-mechanical assessment of partially baked bread during chilling and freezing process. Impact of selected enzymes on crumb contraction to prevent crust flaking

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Abstract

Several problems could arise from the storage of frozen part-baked breads under controlled freezing conditions for a prolonged period of time. One of the major quality problems of this product is crust flaking. The aim of this study was to study the thermo-physical changes provoked by freezing and frozen storage of partially baked bread (PB-bread) and to examine the effect of acid ascorbic, α-amylase, protease and hemicellulase on sub-zero breadcrumb properties by differential scanning calorimetry (DSC) and dynamic-mechanical analysis (DMA). The freezing and frozen storage provoked a retraction of part-baked bread (PB-bread) measured on a French stick; influenced water properties and increased the amylopectin retrogradation in PB-bread as measured by DSC; and modified the shrinking pattern of PB-breadcrumb. It seemed that the contraction stress that developed in the matrix during the freezing process of PB-bread was higher in frozen samples than in non-frozen samples due to the fact that they had a more rapid deformation during ice-crystallization.

Keywords: Chilling; Freezing; Starch retrogradation; Staling; Freezable water; Crumb

1. Introduction

Partially baked bread (PB-bread) has been developed a lot during the past decades. The objective of part-baking is to carry out starch gelatinisation and gluten coagulation, without reaching the colouring reactions of the crust. To retard staling and to extend shelf life of bread, the PB-breads are very often frozen.

Several problems could arise from the storage of frozen part-baked breads under controlled freezing conditions (−18 °C) for a prolonged period of time: (1) crust flaking; (2) deterioration in texture of end products; (3) lowering in loaf volume; (4) structural modification of amylopectin during frozen storage and (5) moisture loss (Bárcenas, Haros, & Rosell, 2003; Cauvain, 1998; Fik & Surowka, 2002; Le Bail et al., 2005; Lucas, Quellec, Le Bail, & Davenel, 2005; Vulicevic, Abdel-Aal, Mittal, & Lu, 2004).

One of the major quality problems of this product is crust flaking. Crust flakes sometimes appear during the final baking. Industrial practice suggests that the freezing step is responsible for this "flaking". No flaking would occur after the final baking step if the bread was not frozen and crust flakes can form even in the absence of cold storage. Le Bail et al. (2005) showed that the chilling condition after partial baking appears to be the most

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influent parameter on crust flaking followed by proving condition. These authors concluded that a higher air humidity during the process tends to minimize crust flaking.

There are two mechanisms used to explain flaking. On one hand, the condensation of water vapour under the loaf crust during the cooling stage. Water crystallization between the different layers of a multilayer material (a first layer of crust, a second layer of relatively pure water, and a third layer of crumb) might give rise to local stresses, which after a sudden evaporation during final baking might be responsible for detachment of the upper crust.

On the other hand, the tensile forces developed within the bread matrix because of the bread structure cannot relax in response to the contraction of the crumb phase during cooling. The tensile forces could make bread matrix more sensitive to mechanical shocks or to high hydrothermal stresses on final baking, which in turn would finally result in a detachment of parts of the crust and flaking phenomena (Lucas et al., 2005).

There is a real need in understanding and optimising the process and the quality of PB-bread. A limited amount of literature is available in this area; therefore much research can still be done to determine the causes of flaking phenomenon. In this work we studied the thermo-physical changes provoked by freezing and frozen storage of PB-bread. Besides, we examined the effects of different additives (acid ascorbic, α-amylase, protease, hemicellulase) on sub-zero breadcrumb properties by DSC and DMTA.

2. Material and methods

2.1. Material

Flour was obtained from a local mill (Soufflet, France). Wheat flour had ash, protein and moisture contents of 0.55%, 11.25% and 14.9%, respectively. Alveographic parameters were W 245; P 65, L 130, P/L 0.5 and G 25.3, and a falling number of 437 s. Acid Ascorbic, gluten and fungal amylase (Bel'Ase A75, 75.000 SKB/g) were obtained from Puratos (Belgium). Protease (Veron PS, >227 U_{Hb}/g) and fungal hemicellulase (>47 UXyIH/g) were obtained from Röhm Enzyme GmbH (Germany). Compressed yeast and salt were purchased in the local market.

2.2. Sample preparation

The dough base formulation (standard dough) used comprised: 2000 g wheat flour, 60% of water (optimum level), 3% compressed yeast, 2.2% sodium chloride and 0.03% acid ascorbic on a flour basis (fb). Table 1 shows compositions of the selected dough formulation prepared in the present study. Mixing was carried out in a spiral mixer (VMI, Montaigu, France) with a 10 l bowl. A 9 min rapid mixing followed slow mixing for 2 min. Salt was incorporated in the mixer after 4 min of rapid mixing. Dough temperature after mixing was 23 ± 1 °C. Dough was divided in portions of 160 ± 2 g and rounded. The pieces of dough were given a 15 min rest period before being moulded with traditional sheeting–moulding equipment (façonneuse PUMA-France). Proving was carried out in a "PANIMATIC" (France) proving cabinet at 30 ± 1 °C and 90% relative humidity for 100 min.

Table 1
Formulations of various wheat PB-breads

Reference	Dough formulation
SD	Standard dough—acid ascorbic 300 ppm (fb)
HE	SD + hemicellulose 300 ppm (fb)
AM	SD + amylase 15 ppm (fb)
AMP	SD + amylase 15 ppm + protease 100 ppm (fb)

Partially baking was carried out in a ventilated oven at 150 °C for 13 min with 300 ml of vapour injection at the beginning of baking. To maintain high humidity levels in the oven, the oven remained closed for 7 min, and it was held open for the last 6 min of baking. The baking uniformity was checked previously by using colour measurement of the crust; indeed, bread located close to the wall of the oven are exposed to higher radiative heat transfer resulting in a different crust conformation.

Postbaking chilling was carried out at room temperature (23 ± 2 °C) for 60 min (time to the bread core reached 30 °C). PB-bread freezing was carried out in a blast air freezer (SERVATHIN, France) with an air velocity of 3 m/s for 60 min. Samples were stored in a plastic pouch for 4 months in a walk in cabinet at −19 ± 1 °C. Sixteen baguettes were produced for each batch.

Thawing was carried out at 30 ± 1 °C for 60 min in the plastic bag (to prevent water condensation in bread surface) and final baking was carried out at 220 °C for 10 min.

The height and the length of the part-baked baguette (French stick) were measured above freezing and after freezing and frozen storage and after final baking.

Bread loaf specific volume was determined by rapeseed displacement and weighed 2 h after final baking. Two replicates were analysed.

2.3. Differential scanning calorimetry (DSC)

Crumb samples of the (frozen and not-frozen) PB-bread core were pressed and portions of 30 ± 5 mg were weighted in a hermetically sealed aluminium pan (30 μl, pans BO14-6118 + cover BO14-6650—Perkin Elmer, USA) and analysed with a Pyris 7 DSC (Perkin Elmer, USA). The DSC was calibrated using mercury, distilled water and indium. An empty pan was used as reference. Samples were fast cooled from ~25 to −50 °C, held at this temperature for 5 min and heated at 2 °C/min from −50 to 100 °C. Dry nitrogen gas flow of 20 ml/min was used to minimize water condensation in the measuring cell. At least duplicated samples were analysed for each dough sample.

The onset (T_o), peak (T_p) and conclusion (T_e) temperatures and the transition enthalpy (J/g) of ice melting and amylopectin retrogradation were calculated. Freezable