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Bread collapse. Causes of the technological defect and impact of depanning time on bread quality

Asma Rzigue [a, b], Jean-Yves Monteau [a, b, *], Khadidja Marmi [a, b], Alain Le Bail [a, b], Sylvie Chevallier [a, b], Anne-Laure Réguerre [c], Vanessa Jury [a, b]

[a] LUNAM University, Oniris, UMR 6144 GEPEA, BP 82225, 44322 Nantes CEDEX 3, France
[b] CNRS, 44307 Nantes, France
[c] INRA, UR 1268 Biopolymers Interactions Assemblies, BP 71627, 44316 Nantes, France

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ABSTRACT

The collapse of the sides of sliced bread is a technological problem for the baking industry. This study aims to understand the possible link between bread structures, internal pressure gradient, waiting time in the pan before depanning, and side collapse. The collapse variation was measured using laser to get bread profiles, and using image analysis of bread slices. The pressure variation at the centre and at the periphery was measured, and the product structure was observed using X-ray microtomography. The collapse increases with the cooling time in pan. The pressure in the cells is always higher than pressure in ambiance and cannot explain the collapse. The bread structure measurements indicate that the collapse is probably due to the cells shrinking of bread sides cells. A complementary explanation is to be searched in the specific volume variation of the material constituting the dough and the bread during the baking and the cooling.

1. Introduction

An important technological problem for the baking industry is the collapse of the sides of sliced bread. This can have an impact on the overall appearance and structure of the bread and affects adhesion of bread to the pan, especially with the presence of a liquid film due to the condensation of water. This liquid film increases adhesion of bread to the pan. Conversely, one of the possible consequences of bread collapse is the weak adhesion of bread to the pan due to the reduced contact area. Thus, bread collapse is closely linked to pan adhesion.

Although bread adhesion to the mold has not been studied until now, problems in industry due to adhesion are varied and not fully controlled. Several works have tried to understand and manage this phenomenon: Mittal (1977) explained that if there was good wettability of a solid by a fluid adhesive, the roughness of the solid improved adhesion. However, if the wettability was low, the roughness decreased adhesion. In the food science field, Leclercq-Perlat et al. (1994) showed the importance of surface defects and porosity for the aptitude to retain adhered microbial contamination.

Other problems due to food-equipment adhesion have been observed during the production of dough (Saunders et al., 1992). Keijbets et al. (2009) showed that the surface properties of the mold have a significant influence on how chocolate adheres and solidifies during the molding process. The separation of solidified chocolate from the mold was dominated by two different failure mechanisms, adhesion failure (separation of two materials at their contact area) and cohesive failure (rupture of a material close to the contact area), depending on the nature of the mold surface.

During baking, bread dough undergoes an expansion followed by a slight contraction at the end of baking. The contraction during baking has been highlighted by several authors but there is a limited amount of literature about the contraction of the crumb during cooling. A study by Ben Aissa et al. (2010) on the contraction of the crumb during cooling after baking and during freezing showed that it was larger for conventional bread than for degassed bread crumb. The shorter the baking time, the larger the contraction of the crumb. Thus, the changes that occur during baking and subsequent cooling are reflected in the final porous bread structure.

* Corresponding author. Oniris, rue de la Géraudière, BP 82225, 44322 Nantes CEDEX 3, France.
E-mail address: jean-yves.monteau@oniris-nantes.fr (J.-Y. Monteau).

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Another study by Lucas et al. (Lucas et al., 2010). About frozen pre-fermented doughs showed that large and elongated bubbles were formed beneath the top surface during thawing. The pieces of dough were then thawed to undergo a second fermentation. There was a collapse of the dough all the more important that the first proving duration was long. The authors hypothesized that these bubbles below the surface contributed highly to this collapse. Ribotta and Le Bail (2007a) studied the contraction of crumb in part-baked bread without searching for its origins. According to Ribotta and Le Bail (2007b), Le Bail et al. (2005), and Lucas et al. (2005), crust contraction has only been proved to have an effect on crust flaking.

In this article, we are interested in the causes of collapse and the sources of adhesion at the cooling stage, related to bread ingredients. The aim of this research is to understand the possible link between bread structure, processing conditions (internal pressure gradient) and waiting time in the pan before depanning, and side collapse of bread. Due to the lack of literature on bread cooling for short times from the end of baking to depanning, we are also interested in the role of the liquid film at the pan interface, which may contribute to bread contraction.

Two phenomena are identified as possible explanations of collapse: i) the contraction of the crumb material, ii) the volume reduction of the gas contained in the cells of the bread. For the first hypothesis, the coefficient of thermal contraction of degassed crumb was determined during post-baking cooling with a dynamic mechanical analyzer (DMA). To study the contribution of cells contraction to bread collapse, the internal pressure during baking and cooling was measured as well as the connectivity of cells by X-ray tomography on the final product. Several innovative methods were developed to quantify the collapse phenomena, such as a touchless laser transducers for the bread profile during depanning and image analysis.

2. Materials and methods

2.1. Dough preparation and bread baking

The flour used for the study is an all-purpose flour type 55 delivered by “Les Grands Moulins de Paris”. The recipe used in this work was based on the following proportions: 100 g wheat flour (dry matter), 53 g water, 1.8 g salt, 4.5 g sugar, 4.5 g rapeseed oil, 2 g compressed yeast (lS.I., Lesaffre), 0.0015 g ascorbic acid and 2 g improver (Nutrixo, France). The mass of dough prepared was 3396 g.

All ingredients were mixed in a spiral mixer VMI SP10 (Montaigu, France) for 5.5 min at low speed (100 rpm/min), followed by 6 min at high speed (200 rpm/min). Water was added after 1.5 min of mixing at low speed and salt at the beginning of the high speed phase. After mixing, dough temperature was between 22 °C and 25 °C. After 20 min of rest, a sample of dough (20 g) was placed in a sterilized flask (5 cm internal diameter) to control the dough expansion ratio during proofing.

Dough was divided into pieces of 560 g that were allowed to rest for 20 min. Then, the dough pieces were rolled mechanically in a molder L'Artisanne 2004 (SARL DELEUME, Nevers, France). The dough stick was divided into 4 equal parts, which were introduced in the direction of the width of the pan. Pans (10 × 10 cm) were coated with a nonstick coating, limiting the adherence of the dough. At the end of proving, dough is around 3 cm from the rim of the pan.

The pans and the flask containing 20 g dough sample were placed in a fermentation cabinet Panimatic P1DB 12.89 (Souppes-sur-Loing, France) at 37 °C, 85% relative humidity, until the dough expansion ratio reached 3.

Baking was done in a deck oven Bongard M2 Soleo (Holtzheim, France) at 230 °C for 25 min. Bread was cooled at room temperature by natural convection. The ambient temperature and relative humidity were not controlled.

2.2. Thermal coefficient of expansion

First of all, degassed dough samples were prepared; 20 g of dough was extracted from the fermented dough at the end of the fermentation. The 20 g sample was first gently squeezed manually to partially remove out of the dough sample the gas caused by the fermentation. Then the dough sample was placed in a plastic pouch. The sample was vacuum treated for 1 min to remove the remaining gas contained in the dough. A full description of the system is available in (Le-Bail et al., 2009). Then, the evolution of the volume of degassed crumb was determined using a dynamic mechanical analyzer DMA Q800 (TA-Waters Instruments, Milford, DE, USA) with a parallel plate geometry of 6 mm diameter. A static force of 0.05 N was applied to press the sample onto the upper plate of the DMA. Two cycles of heating and cooling were applied: first the sample was heated to 98 °C then cooled to 35 °C. The crumb thickness was plotted as a function of the temperature of the sample. The temperature scanning rate was 1 °C/min.

The thermal coefficient of expansion is given by Equation (1):

$$\alpha = \frac{1}{L0} \times \frac{dL}{dT} \tag{1}$$

where α is the thermal coefficient of the crumb (1/K), $L0$ is the initial crumb thickness (μm), and dL is the crumb deformation (μm) for an increase in temperature of dT (K).

2.3. Depanning force and bread profile

A depanning bench was designed to measure depanning forces and bread profile simultaneously using an Instron LR5K universal testing machine (Lloyd Instruments, Fareham, UK). It was equipped with two laser transducers detecting bread width and the distance between the bread and the lasers during depanning. The bread was fixed to the mobile unit of the Instron with a device consisting of ten indents (cylindrical steel needles, 2 mm in diameter) which were inserted in the bread before depanning. The depanning speed was 500 mm/min and was carried out with a stroke of 150 mm. The force needed to depan bread was measured as a function of the vertical displacement of the mobile unit. Depanning was done at different times (5, 10, 15, 20, 25 min) after baking to determine the impact of the waiting time on the bread profile, the depanning force and moisture condensation.

2.4. Bread collapse measurement

The internal geometry profile of the pan was measured via wireless lasers while depanning an expansible foam, which fitted exactly the internal surface of the pan. This pan profile was compared to bread profiles during depanning to study the collapse for several times of cooling.

The bread collapse area was determined by comparing the area of the pan cross-section with that of the bread cross-section, computed using image analysis. 2D color images of 10 scanned slices of thickness 1 cm taken at the centre of bread were converted into monochromatic images with gray levels ranging from 0 to 255. Gray-level histograms of all scanned slices were examined together. A gray-level threshold of 100 was visually determined to extract the slices from the background. The final region of interest corresponding to crumb was obtained by erosion of the mask of the slice