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Effect of baking conditions and storage with crust on the moisture profile, local textural properties and staling kinetics of pan bread

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ABSTRACT

To investigate the impact of baking conditions on staling kinetics and mechanical properties, pan breads were baked at 180 °C/34 min and 220 °C/28.6 min using a ventilated oven and metallic moulds. After baking, bread slices were stored with and without crust at 15 °C in hermetic boxes for 9 days. This investigation provides a textural and physical analysis by examining the Young's modulus, crumb density and crust/crumb ratio during storage. In order to understand the relationship between firmness and moisture content, a moisture profile and a Young's modulus profile were determined during the storage of bread. To fit the staling, a first order model was used. It was found that the kinetics were faster for samples baked with a fast heating rate than for those baked with a slow heating rate. Moreover, the staling rate of bread stored with crust was faster than for bread without crust and the outer crust area staled more rapidly than the centre of the bread slice. These results suggest that the firming of the crumb is related to moisture distribution between the crumb and crust and to the impact of local baking conditions on local firmness.

1. Introduction

Bread staling is a complex phenomenon that involves changes in the properties of the crust and the crumb and in which water plays a significant role (Bechtel, Meisner, & Bradley, 1953). Although crust staling is associated with the migration of moisture from crumb to crust resulting in a soft and leathery texture, crumb staling is more complicated and is the result of physicochemical changes in bread starch (Bhatt & Nagaraju, 2009).

Pan bread or sandwich bread usually has a thin crust and a crumb with regular porosity, thin- walled cells and a typical structure different from other types of bread. Its texture is soft and elastic thanks to the presence of fat, monoglycerides, milk powder, sugar in the formula of pan bread. Concerning the bread-making process, pan bread is baked in pans with or without a cover leading to a typical process of crust formation. However, this product has a short shelf life and stales rapidly depending on different factors: the bread-making process, storage conditions (room temperature, relative humidity, storage with or without crust) and baking conditions.

In fact, baking time and temperature have an impact on the morphology and texture of bread and on its quality (specific volume, crust colour, crust/crumb ratio, crumb firmness and moisture content). This morphology affects the kinetics of moisture transfer during aging and, consequently, the mechanical properties. Among the different physical properties which can be considered as characterizing bread, porosity is important not only for the mechanical properties of the crumb but also for moisture transfer within the product. Błaszczak, Sadowska, Fornal, and Rosell (2004) found that during staling, porosity decreased and crumb pores became smaller and rounder. Caballero, Gomez, and Rosell (2007)reported that bread crumb shrinks during storage.

In addition to baking conditions, modifications of the bread-making process have an impact on physical properties. According to Poinot et al. (2008), the introduction of a partial baking stage in the baking process influenced the density of bread and led to a compact crumb. Moreover, they found that varying the recipe of breads had an impact not only on the density, but also on the crust/crumb ratio. This ratio is of great interest when it is used to compare the kinetics of crust setting of breads baked at different temperatures.

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To evaluate bread staling, physical, chemical and textural quality characteristics and sensory attributes have been considered. Moisture (crust and crumb), springiness and mouthful are the most sensitive quality attributes that deteriorate significantly after a few days of storage. The firmness of the final product is most often measured because of the strong correlation between crumb firmness and consumer perception of bread freshness (Carr, Rodas, Della Torre, & Tadini, 2006). Another correlation exists between crumb firmness and moisture content, meaning that there is a relationship between the staling rate and the dehydration rate. Piazza and Masi (1995) made this type of correlation by considering the mass transport phenomenon involved in the process and using a mathematical model.

To evaluate the texture of bread, traditional methods based on a static compression mode, such as texture profile analysis (Carson & Sun, 2001) (determined using a texture analyzer), firmness (based on force-deformation), stress relaxation, penetration, and compression tests have provided data about bread crumb mechanical changes associated with the staling process (Angioloni & Collar, 2009). Many parameters are used to evaluate bread staling such as the Young's modulus determined by Dynamic Mechanical Analysis (DMA), the melting enthalpy of amylopectin and the amount of freezable water, measured by differential scanning calorimetry (DSC) (Ribotta & Le Bail, 2007). Other aspects related to staling may also be considered such as the loss of resilience. Goasaert, Slade, Levine, and Delcour (2009) measured the firmness and resilience of bread after 6 days of storage using a texturometer and concluded that an increase in crumb firmness led to a decrease in crumb resilience due to a less flexible gluten network.

Few researchers have reported the impact of baking time, temperature and storage with or without crust, on the staling rate and the shelf life of bread following storage. Le Bail, Boumali, Jury, Ben-Aissa, and Zuniga (2009) studied the impact of heating rates of 13, 9.8 and 7.8 °C/min, corresponding to 220 °C, 200 °C and 180 °C, on the staling rate of bread baked in a static single oven, with steaming. Baik and Chinachoti (2000) studied the effect of crust on the staling of pan bread. However, no research has been done on the combined effect on staling of both baking conditions and storage with crust. Other researchers studied the impact of the duration of the plateau of baking (this corresponds to the phase of baking when the temperature remains constant) on staling kinetics and reported that low temperature and a long plateau of baking induced a decrease in crumb firmness in the final bread (Le-Bail, Agrane, & Queveau, 2012). Ben Aissa, Monteau, Perronnet, Roelens, and Le Bail (2010) found that the duration of baking influenced the degree of phase separation between amylose and amylopectin and therefore interacted with the mechanical properties of the crumb after baking and during staling. It was observed that the amount of soluble amylose tends to increase with the baking duration.

The effect of baking conditions on starch properties has also been investigated. Patel, Waniska, and Seetharaman (2005) showed that the heating rate during baking affects the extent of starch granule hydration, swelling, dispersion and the extent of reassociation. Consequently, it has an influence on the development of firmness following baking.

The aim of this study was to assess the combined effect of baking conditions and the storage with crust on the physical properties (crumb density, crust/crumb ratio) and mechanical properties of pan bread during staling. A new approach was used, consisting of determining potential staling gradients to study the effect of storage with crust and baking conditions on firmness profiles within a bread slice; a correlation between local moisture content and crumb firmness was investigated. To fit the evolution of the texture during storage at 15 °C, a first order kinetic model was used.

2. Material and methods

2.1. Basic ingredients

Wheat flour was provided by Paulic (Moulin du Gouret, France). The flour characteristics (given by the company) were as follows: 14.9% (d.b.) moisture, 11.4% (d.b.) protein, 0.59% ash (d.b.) and 412 s falling number. Alveographic parameters were: Tenacity ($P = 64$ mm), Extensibility ($L = 116.36$ mm), Ratio Tenacity/Extensibility ($P/L = 0.55$), Deformation energy ($W = 201 \times 10^{-4}$ J). This flour didn't contain improvers. The ingredients used for the recipe were: commercial compressed yeast (Michard SAS – Theix, France), salt (Esco, Levallois Perret, France S.A.), sugar (Béghin Say, France), dry milk powder (Régilait, France), sunflower oil (TransGourmet-Senia 524-Orly, France), ascorbic acid and calcium propionate (Merk Schuchardt OHG-Hohenbrunn, Germany).

2.2. Dough and bread preparation

The basic dough recipe of pan bread contained 2000 g of wheat flour, 1140 g of water, 40 g of salt, 40 g of milk powder, 40 g of sugar, 40 g of sunflower oil, 80 g of yeast, 0.2 g of ascorbic acid and 10 g of calcium propionate.

All ingredients were mixed in a spiral mixer (VMI SP10, Montaigu, France) for 4 min at low speed (100 rpm/min), followed by 11 min at high speed (200 rpm/min). The initial temperature of water was 29 °C, the room temperature was 19 °C ± 2 °C and the flour temperature was 10 °C. The ingredients were added in this order: water, yeast, flour, salt, milk powder, sugar, ascorbic acid and oil. After mixing, the dough temperature was 25 °C ± 1.3 °C. One batch was prepared and, after 9 days of staling study of breads, another batch was used as a replicate. From the batch, 4 pieces of dough of 770 g each were rested for 20 min before being moulded using an automatic moulder (MB230 JAC). Each piece of dough was placed in a metallic mould (10 cm × 10 cm × 30 cm), without a cover. Proofing was carried out in a fermentation cabinet (Panimatic, France) at 35 °C, 95% RH for 70 min to obtain an expansion ratio of about 3. The expansion ratio was evaluated using a small sample of 20 g of dough placed in a cylindrical flask; the dough was placed in the bottom of the flask and its vertical expansion was measured to evaluate the expansion ratio of the dough during fermentation. The dough fermentation time was similar for all dough batches.

When fermentation was completed, the moulds were placed in a ventilated 'Sofinor' oven to be baked at 180 °C or 220 °C. After fermentation, the core temperature of the dough was 30 °C rather than 35 °C (temperature of the fermentation cabinet); this difference was due to the fact that the large mass of dough in the pan slowed the temperature rise during fermentation. The two sides of the mould were perforated in three places to introduce K-type thermocouples (Omega, France) of 0.5 mm diameter for measuring the temperature during baking. In fact, three thermocouples were installed along each side of the mould. One was located at the centre (4 cm deep) and two were located midway between the centre and the ends of the pan (2.75 cm deep). So, in the total, six thermocouples were used: two to record the temperature in the centre of the bread (at 4 cm deep) and four thermocouples were used to record the temperature near the side (at 2.75 cm deep).

The thermocouples were held by a metallic frame made of a thin stainless steel rod (1 mm diameter). The temperatures of these three thermocouples were averaged. The thermocouples were connected to a data logger (SA 32-AOIP-France). The end of baking