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Impact of baking conditions and storage temperature on staling of fully and part-baked Sangak bread

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ABSTRACT

Bread staling involves a combination of physico-chemical phenomena that leads to a reduction of quality. This study aims at evaluating the impact of baking conditions (280 °C, 8 min; 310 °C, 5.5 min; 340 °C, 4 min), baking type (of fully baked (FB) and part-baked (PB)) and storage temperature (−18, 4 and 20 °C) on the staling of Sangak bread. Results showed that lower baking temperature with longer baking time produced drier bread with higher firmness. In FB Sangak breads, amylopectin retrogradation, amount of unfreezable water and firmness (measured by compression test) increased during storage at positive temperatures but hardness (determined by Kramer shear test) decreased significantly during first day of storage. The recrystallized amylopectin traps the free water resulting in crumb hardening. Water is also absorbed by the dry crust resulting in changes of rheological properties in the crust and crumb, and finally in staling. Storage at 4 °C resulted in increasing melting enthalpy of amylopectin crystallite in comparison with storage at 20 °C. Also it was found that firmness of PB breads due to rebaking was significantly lower than FB breads. There were no significant changes in staling parameters of FB and PB stored at −18 °C.

1. Introduction

Sangak bread is one of the most widely used flat breads in Iran. This traditional bread is prepared from whole wheat flour and has a high nutritional value (Qarooni et al., 1992). It has a triangular shape with 0.5–1 cm thickness which is traditionally baked on a bed of hot gravel preheated in a specific traditional oven at 250–350 °C for a few minutes. Sangak dough has higher moisture content and lower consistency than conventional bread dough. The amount of water in Sangak dough formulation is 85–100% (depends on flour quality) on a flour basis while this is 50–60% for most of the bread doughs (Qarooni, 1996). Unfortunately, an important part of Sangak production is lost due to staling. Despite extensive studies available on staling phenomenon, staling still is a problem.

Bread staling involves both parts of crust and crumb. In flat breads, crust is just a very thin layer so bread staling is mostly related to physicochemical changes of crumb. Amylose recrystallization occurs during the first hours after baking, whereas amylopectin retrogradation occurs over a much longer period of time (i.e. several days after baking) (Gray and Bemiller, 2003). Interactions between starch and gluten, moisture migration and redistribution of water among components (from gluten to starch) occur in bread firming and occur during aging (Miles et al., 1985; Gray and Bemiller, 2003).

Researchers and the baking industry have attempted to postpone staling by applying different methods such as changes in the bread making process (fermentation, baking and chilling conditions and part-baking process), changes in formulation (addition of some additives such as enzymes, emulsifiers and hydrocolloids) and changes in storage conditions (Ahmadi Gavilighi et al., 2006; Bárcenas et al., 2003a,b; Bárcenas and Rosell, 2006a,b; Le-Bail et al., 2009, 2011, 2012).

Abbreviations: DSC, differential scanning calorimetry/calorimeter; FB, fully baked; FW, freezable water; ΔH_f, enthalpy of fusion (J/(gdm)); ΔH_r, melting enthalpy of amylopectin (J/(gdm)); LSD, least significant difference; NMR, Nuclear magnetic resonance spectroscopy; PB, part-baked; T_g, glass transition temperature; T_m, melting temperature; T_o, onset temperature; T_i, initial temperature; T_p, peak temperature; T_c, conclusion temperature; UFW, unfreezable water.

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The part-baked bread is a semi-finished product with sufficiently rigid structure so that its preparation for consumption is easy and rapid. The objective of the part-baking is to carry out the gelatinization and the coagulation of the gluten, without reaching the reactions of coloring on the crust (Roussel and Chiron, 2002). Part-baking process consists of two stages; in the first stage, the fermented dough is baked under the defined oven conditions into part baked product with proper crumb texture and minimum crust coloration. After a storage time, the second baking process is done at the serve time to create the appropriate flavor and crust color (Morgenstern, 1985).

Baking duration and temperature are two key parameters related to the bread making process and may affect the final mechanical properties of the bread and therefore staling rate (Le-Bail et al., 2009). Several studies on effect of baking temperature and its duration on bread staling are available in the literature (Smith et al., 1983a; Leuschner et al., 1999; Faridi and Rubenthaler, 1984). Maleki et al. (1980) reported that breads with higher moisture content were initially softer and remained softer up three days of storage than breads with lower moisture. Le-Bail et al. (2012) observed that Young's modulus of degassed crumb and of conventional crumb was increasing with decreasing heating rate. On the opposite to their observations, Patel et al. (2005) reported that a faster heating rate resulted in a harder crumb, in a higher enthalpy of melting of amylopectin crystallites and in a larger amount of leached amylose. Hoseney et al. (1978) proposed that amylose leached by the starch granules during baking envelop the swollen granules and contribute to the setting of the crumb structure in bread and to its firmness. Duration of baking has an influence on the degree of destruction of starch granules as shown by Borczak et al. (2008). The location of the loaves in the oven can also induce a difference between baked breads. Indeed, the loaves that are placed close to the wall of the oven may heat up at a different rate than the bread placed at the center of the oven.

Production of part-baked products and also freezing of bakery products are efficient solutions to control staling (Bárcenas et al., 2003a). Although freezing is appropriate in extending the shelf life of bread, the quality of frozen bread can be affected in comparison to fresh bread. Different researchers have studied the effect of freezing on quality of fully baked and part-baked breads during storage (Ronda et al., 2011; Bárcenas et al., 2003a; Bárcenas and Rosell, 2006b; Gujral and Singh, 2008; Cauvain, 1998). The nucleation-growth process of amylopectin crystals is enhanced by freezing treatment at temperatures above the glass transition temperature (T_g). Thawing and storage at higher temperatures can result in the growth and maturation of crystals and therefore in an increase of recrystallization rate in comparison with unfrozen systems (Ronda and Roos, 2008). However, it seems that the maximum staling rate is in the range of −10 °C to 5 °C. Therefore, storing fully baked and part-baked breads in refrigerator (i.e. 4 °C) increases the shelf life with respect to risk of mould growth but accelerates the staling in storage at room temperature because being in the optimum temperature range (between glass transition (T_g) and melting temperature (T_m)) to balance nucleation and crystallization of amylopectin (Slade and Levine, 1987).

There are different methods to evaluate intensity and degree of staling which the most common are evaluation of bread texture, determination of some thermal properties (melting enthalpy of retrograded amylopectin, amount of freezable water, ice melting transition and their temperature ranges), measurement of soluble starch and enzyme digestibility, conductance and capacitance, infrared spectroscopy, Nuclear magnetic resonance spectroscopy (NMR), X ray crystallography and microscopy (Gray and Bemiller, 2003).

The review presented above shows that the processing and storage conditions of bread play an important role in the staling. However, to our knowledge, no previous researches have studied combination of baking type (full or partial baking), baking condition (temperature − time) and storage temperature on staling of the flat bread produced from dough with high water proportion and whole flour such as Sangak.

This research is part of a study on the part-baked Sangak bread to provide a better understanding of the involved phenomena in its baking process and storage. The objectives of the present study were (1) to investigate the effect of part-baking compared to full baking on the staling of Sangak bread and (2) to evaluate the ageing properties of FB and PB Sangak breads baked at different temperatures during storage at different conditions (frozen, refrigerated and room temperature).

2. Material and methods

2.1. Raw materials

Wheat flour with high extraction (typically 95%) is common for preparing the Sangak bread. Flour was purchased from a local milling plant (Isfahan, Iran). The chemical composition of the wheat flour on a wet basis was 1.01% ash, 13.7% proteins, 2.02% lipids, and 13.2% moisture. Other flour properties were 27.8% wet gluten, 9.5% dry gluten, 50.5% gluten index and 63.5% water absorption obtained from Farinograph test (AACC, 2000). Dried active baker yeast was obtained from Fariman Co., Iran.

2.2. Fully baked (FB) and part baked (PB) Sangak bread preparation

Sangak dough was produced using the following formula: 100 g whole wheat flour, 100 g water (25 °C), 1 g salt and 1 g dried active yeast. The ingredients were mixed in a spiral mixer (VMI, Montaigu, France) for 7 min at low speed and 8 min at high speed. Then, dough which is rather a batter, was fermented for 45 min at 30 °C and 75–85% relative humidity in a proofing cabinet. The dough was sheeted to 3.5 mm thickness and frozen at −30 °C. After 24 h storage at −20 °C, the frozen dough sheet was cut in pieces of 15 × 15 cm just before baking. Full-Baking was done in a forced convection oven (MIWE-Germany) at 280, 310 and 340 °C for 8, 5.5 and 4 min, respectively. Part-baking was carried out with 70% of the time required for full-baking; with such condition, the crumb appeared as baked while the crust of the bread was still uncolored and able to undergo a final baking. Cooling of breads was done at room temperature and considered as completed when the temperature of the bread crumb reached 20 °C. Finally, the part-baked breads were packed in sealed impermeable films, part of them being frozen at −30 °C and stored at −18 °C for 12 weeks (sampling intervals was 0, 1, 2, 4, 6, 8, 10 and 12 weeks). The rest of the samples was stored at 4 and 20 °C for 14 days (sampling intervals was 0, 1, 3, 8 and 14 days) and 4 days (sampling intervals was 0, 1, 2 and 4 days), respectively. For analyzing the staling process, the frozen FB samples were thawed at room temperature for 1 h before the experiments. The frozen PB samples were re-baked at 280 °C for 3 min, 1 h before the analysis.

2.3. Differential scanning calorimetry

A differential scanning calorimeter (DSC Q100, TA Instruments, USA) was used to determine the thermal properties (onset temperature (T_o), initial temperature (T_i), peak temperature (T_p), conclusion temperature (T_c), enthalpy of fusion (ΔH_f, J/(g$_{dm}$)) and melting enthalpy of amylopectin (ΔH_r, J/(g$_{dm}$)) of Sangak crumb at atmospheric pressure. DSC was calibrated using indium, deionized water and isopropanol. Samples (80–90 mg) were taken from the