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Influence of frozen storage and packaging on oxidative stability and texture of bread produced by different processes

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ABSTRACT

The influence of packaging barrier properties and frozen storage on phenolic and phytosterol content, oxidative stability and crumb texture of frozen dough, part-baked and fully baked frozen bread was investigated in comparison to conventionally produced bread. Samples were stored either in blue coloured high density polyethylene (PE-HD) or transparent polyester-polyethylene-ethylene-vinyl alcohol copolymer (PET-PE/EVAL/PE) pouches for 22 days at −18 °C. Packaging materials were different in oxygen permeability: 3.67 $cm^3m^{-2}day^{-1}$ bar^{-1} for PET-PE/EVAL/PE and 2080 $cm^3m^{-2}day^{-1}$ bar^{-1} for PE-HD material, which did not significantly change during storage. Total phenolic content and oxidative stability of bread samples decreased during storage depending on the process. Frozen dough bread had the lowest phenolics decrease and the highest oxidative stability. Total phenolic content and oxidative stability of frozen breads during 8 days were similar to conventional bread. The phenolics reduction was higher for samples stored in PET-PE/EVAL/PE laminate than in PE-HD packaging. Total sterol content did not significantly change during bread storage in investigated packaging and did not contribute to the oxidation. Bread firmness was affected only by the process and not by the storage time and packaging material.

1. Introduction

Bread is a widely consumed food that has a relatively short shelf life. During storage rapid loss of flavour and changes in bread texture such as increased hardness and fracturability, decreased elasticity and solubility occur. Bread becomes dry and hard mainly due to starch retrogradation (Armero & Collar, 1998) but also because of cross-linking between continuous protein matrix and discontinuous starch granule remnants with hydrogen bonds (Martin, Zeleznak, & Hoseney, 1991). Moreover, during storage, water relocates from the bread crumb to the crust and the total water in crumb reduces (Baik & Chinachoti, 2000). Those changes are major factors contributing to bread staling that very negatively influence consumer acceptance and cause economical loss (Cauvain, 1998; Gray & Bemiller, 2006). Staling rate depends on bread size, moisture content (Zeleznak & Hoseney, 1986), production process and packaging (Cauvain & Young, 2000a). There are different techniques for storage life extension, such as reduced temperature and optimal packaging application. New technologies, popularly called bake-off, that involve partially baked bread and frozen dough processes are on the rise constantly (Giannou & Tzia, 2007; Havet, Mankai, & Le Bail, 2000; Le Bail, Grinand, Le Cleach, Martinez, & Quilin, 1999; Vulicevic, Abdel-Aal, Mittal, & Lu, 2004). They are aiming to offer the consumers freshly baked bakery products in retail and households with nutritive and sensory quality as close to the conventional bread.

Bread packaging is a proven tool for shelf-life extension but also adds cost to the product. Its principal function is to minimize reactions that affect bread stability. In most cases, the environmentally present gaseous reactants (water vapour, oxygen) can seriously restrict stability under the usual food storage and distribution conditions (Rizvi, 1981). Thus, the rate of transport of such reactants across the partial barrier of the package wall can become the limiting factor for product shelf life (Devlieghere & Debevere, 2003; Robertson, 1993). The shelf life of a packaged product depends on a series of variables associated with the product's composition and processing, its packaging material and storage conditions (Rellmann & Schenck, 1992). Packaging material for frozen dough and part-baked bread must keep product moisture loss at minimum. It has to have good oxygen-barrier characteristics, physical strength against breakage at low temperature, good heat sealability and low cost (Cauvain & Young, 2000b).

The deterioration of food with time is inevitable and from a chemical view, oxygen is directly involved in food deterioration.

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Bread oxidative stability is strongly affected by temperature, presence of air or oxygen, light, and lypolytic enzymes. Naturally, wheat contains fat-soluble antioxidants, such as tocols, ferulic and caffeic acid esters and carotenoids, and water-soluble antioxidants, such as phenol acids and glycated flavonoids (Kanski, Aksenova, Stoyanova, & Butterfield, 2002; Miller, Rigelhof, Marquart, Prakash, & Kanter, 2000; Yu, Vasanthan, & Tamelli, 2001). Some sterol compounds such as Δ5-avenasterol, Δ7- avenasterol and citostradienol have antioxidative activity but some can be prooxidative (Gordon & Magos, 1983). Among other cereal substances, polyphenols and phytosterols are often called bioactive substances because of their beneficial effects on human health. In addition to the health benefits, phenolic acids interfere with dough formation (Piber & Koehler, 2005; Wang, van Vliet, & Hamer, 2004) and effect bread sensory profile as they are perceived as sour, bitter and astringent (Lesschaeve & Noble, 2005). For their antioxidative activity, phenolic compounds can be used as the indicator of packaging features.

In previous studies, the effect of bake-off technology on bread quality parameters and microbial stability has been studied intensively (Barcenas, Haros, Benedito, & Rosell, 2003; Carr, Rodas, Della Torre, & Tadini, 2006; Curic et al., 2008; Giannou & Tzia, 2007; Karaoglu & Kotancilar, 2006; Karaoglu, Kotancilar, & Gurses, 2006; Vulicevic et al., 2004). However, no research has focused on the impact of frozen process and storage on the bread oxidative state. The aim of this investigation was to evaluate the influence of packaging barrier properties on bread oxidative stability during frozen storage. The total phenolic content, sterols, oxidative stability, moisture content and crumb firmness of fully or part-baked bread and bread from frozen dough during 22 days of frozen storage in two different packaging materials were determined.

2. Materials and methods

All breads were made from wheat flour (Moulins Soufflet Pantin, France) characterized by moisture content 14.4 g/100 g, protein 9.02 g/100 g, ash 0.52 g/100 g, wet gluten 24.9 g/100 g, falling number 450 s, water absorption 53 g/100 g, dough development time 2 min, dough stability 5.6 min, dough strength 58 BU, degree of softening 60 BU, extensibility 0.113 m and maximum viscosity 1060 AU. Because of rather low flour quality an improver containing emulsifier, enzymes and ascorbic acid (Puratos, Belgium) was used in bread-making. Breads were stored either in blue coloured 0.02 mm thick high density polyethylene (PE-HD) and transparent 0.04 mm thick laminate material consisted of low density polyethylene (PE-LD) as food contact layer, ethylene vinyl alcohol copolymer as barrier layer, and polyester-adhesive resin-PE-LD as other layers (PET-PE/EVAL/PE).

2.1. Experimental procedure

The conventional bread recipe consisted of flour 10 kg, water 5.8 kg, salt 0.2 kg, compressed yeast 0.5 kg, and improver 0.1 kg. Partially baked bread was prepared from 10 kg of flour, 5.2 kg of water, 0.2 kg of salt, 0.2 kg of compressed yeast and 0.1 kg of improver. The unfermented frozen dough recipe was: flour 10 kg, water 5.6 kg, salt 0.2 kg, compressed yeast 0.5 kg, and improver 0.3 kg. Dough was mixed in a spiral mixer (SP40F, Diosna, Germany) 2 min at 90 rpm and 7 min at 180 rpm. Dough, for each process, after resting for 10 min, was divided into 70 g pieces and then rounded. Dough for conventionally bread-making was proofed at 35 °C and 95% relative humidity for 60 min and baked at 230 °C for 17 min with 0.5 L steam at start. Dough for part-baked bread was proofed at 34 °C for 105 min, baked at 190 °C for 3 min with 0.2 L steam at start followed by baking at 165 °C for 14 min. Unfermented dough, a portion of fully baked breads and part-baked breads after cooling at room temperature for 30 min were frozen at −22 °C in a blast freezer. The bread formulations were provided by partners of the European project FOOD-2006-36302 EU-FRESH-BAKE.

Frozen dough, part-baked and fully baked breads were packaged either in PE-HD or PET-PE/EVAL/PE pouches and stored in a freezer at −18 °C for 1, 8, 15, 22 days. Six bread samples corresponded to the contents of one package. Conventionally produced bread was not subjected to freezing or packaging.

After storage, frozen dough was thawed for 60 min at room temperature, proofed and baked in the same manner as the conventional bread. Partially baked frozen bread was thawed at room temperature for 10 min and baked at 230 °C for 10 min.

2.2. Packaging barrier properties

Once the breads had been sampled, the packagings were analyzed for barrier properties. Oxygen permeance through packaging material was determined by a manometric method using permeability testing appliance (Type GDP-C, Brugger, Germany). The packaging sample was put between the top and bottom part of permeation cell. Prior to each test the bottom part of permeation cell was evacuated. During testing the top part was filled with the test gas. The gas permeating the material caused the increase of pressure at the bottom part of permeation cell that was recorded (Brugger Feinmechanik Manual, 2003; DIN 53536, 1992). Water vapour transmission rate was determined according to the gravimetric method (DIN 53 122, 1974; ASTM: E 96-80, 1981).

2.3. Total phenolics content determination

Six bread samples were cut in cubicles sized approximately 1 cm^3 and dried at 40 °C for 20 h. The ethanolic extracts were prepared as described by Yu, Haley, Perret, and Harris (2002). Approximately 8 g of dried sample was extracted for 3 h with absolute ethanol using a Soxhlet extractor. The extract was diluted with absolute ethanol in a 100 mL volumetric flask. The total phenolic content of ethanolic extracts was determined using the Folin-Ciocalteu reagent (Yu, Haley, Perret, Harris, Wilson et al., 2002). Reaction was carried out on the 100 μL of ethanolic extract with 500 μL of the Folin-Ciocalteau reagent and 1.5 mL of 20 g/100 g sodium carbonate. The blue colour absorbance was measured at 765 nm (HEλIOS β UV–VIS Spectrometer, UNICAM, Portugal) against a blank after 2 h of reaction at ambient temperature. Gallic acid was used as a standard and the results are expressed as mg/kg dry bread.

2.4. Evaluation of bread oxidative stability

Fat content in bread samples was determined according to the ISO Standard 7302 (1999). Pure lard was used as the lipid substrate to evaluate lipid oxidation inhibition activity of the breads antioxidant extracts. Ethanol in aliquots of extracts prepared as described in 2.3, was evaporated under vacuum (DEVAROT 4, Elektromedicina, Slovenia) and a dry extract was weighted. The dry extract was dissolved in 2 mL of absolute ethanol, and lard was added to obtain 0.02 g/100 g of the extract. The solvent was removed at 40 °C under vacuum. The same solvent volume, instead of the extract, was added and evaporated from the control sample (lard). 6 mL of sample was heated in the Rancimat equipment (Metrohm 679, Herisau, Switzerland) at 110 °C with a continuous air flow of 20 L/h. The conductivity cells were filled with 60 mL of deionized water (2 μS/cm). A time needed for the appearance of a sudden water conductivity rise, caused by the adsorption of volatiles deriving from oil oxidation, was registered as the