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Quality and shelf life of calcium-enriched wholemeal bread stored in a modified atmosphere

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A B S T R A C T

Calcium-enriched wholemeal bread packed in a modified atmosphere (60% CO_2, 40% N_2), was examined for stability and microbiological changes throughout 32-day storage. The product was still acceptable after 24 days at 20 ± 1 °C. At this time no microbiological changes were observed; however, there was a continuous decline in sensory quality, mainly due to deterioration of the texture. Crumb hardness increased, whereas its springiness and cohesiveness decreased. These observations were accompanied by physical and chemical changes characterized by a steady increase in acidity and a sharp decrease in blue value, especially at the beginning of storage. The first microbiological changes occurred only after 27 days of storage and were due to the growth of moulds and amylase-negative Gram-positive cocci, cocci-bacillus or bacillus. The principal component analysis showed that nearly 86% of the variance in ten considered variables could be represented by two new variables: PC1, defined by eating quality and physicochemical attributes, and PC2 defined mainly by chewiness. Three groups of stored bread were identified on the score plot. The first group, fresh and 3-day stored bread, was characterized by low hardness and sourness; the second, bread stored from six to twenty days, scored lower for overall sensory quality, low springiness, cohesiveness and blue value; and the third group, the product during the final stages of storage, exhibited a clear increase in chewiness and hardness and showed the first indications of microbial deterioration.

1. Introduction

Bakery products are characterized by short-term stability and limited shelf life due to the rapid course of staling (Fik, 2004). This complex and not fully investigated process is generally believed to stem from manifold changes in the composition of bread, caused by factors other than microbial growth, which result in a loss of freshness and a reduction in quality. Such changes cause a deterioration of both sensory attributes and physicochemical properties, especially in the structure and texture of the bread's crumb and crust. The reduction observed in starch solubility is also a significant factor, correlating with increasing starch recrystallization and a fall in water holding capacity in the bread crumb during storage (Hoseney and Miller, 1998). The intensity of such processes increased throughout storage depending on the conditions applied, resulting in the following changes being observed: an increase in the hardness, dryness and crumbliness of the crumb along with a fall in its elasticity; a decrease in the crispness of the crust; and a decline in aroma and other characteristic attributes of bread freshness. All this is evidence of staling, an indicator of the limited shelf life of bread and a phenomenon that may to some extent be explained by moisture migration from the crumb to the crust due to changes in colloid structure (Burrington, 1998) and not necessarily by moisture loss. Thus, retaining the freshness of bread remains an important problem for both consumers and bakers, which explains why bread ageing and the retardation of this process are widely reported in the literature (Fik and Celej, 1993; Fik et al., 2000; Gerrard et al., 1997; Patel et al., 2005).

The practice of packaging and storing bread in a modified atmosphere (MAP) is becoming increasing common as a method of extending its shelf life and maintaining good quality. Many authors have confirmed the benefits of this method in the storage of bakery products (Smith, 1993; Kotsianis et al., 2002). Some of them emphasize its role in extending the microbial shelf life of bread (Phillips, 1996). According to Smith (1993), the application of MAP

Abbreviations: A, acidity; BV, blue value; C, cohesiveness; CAP, controlled atmosphere packaging; Ch, chewiness; H, hardness; MA, modified atmosphere; MAP, modified atmosphere packaging; MC, moisture content; OSQ, overall sensory quality; PCA, principial component analysis; PC1, principial component 1; PC2, principial component 2; S, springiness; TPA, texture profile analysis; WHC, water holding capacity.

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extends shelf life in three ways: chemically, it controls biochemical and degradation processes and slows oxidation; microbiologically, MAP may increase shelf life by inhibiting the growth of mould and bacteria; and physically, MAP lengthens a product's stability by reducing moisture loss. It is similar to controlled atmosphere packaging (CAP) in that a specific gas mixture is applied to the product but differs in the level of control. Bread can be packed in a modified atmosphere in order to delay staling and hinder the growth of moulds using 60% to 80% (v/v) carbon dioxide and 20% to 40% nitrogen.

Since bread is one of the most frequently consumed food products, it is reasonable to enrich it with nutritive substances. Commonly supplemented with protein preparations (Begum et al., 2011), bread is also frequently fortified with minerals (Karadzhov and Iserliyska, 2003) and vitamins (Czeizel and Merhala, 1998). Antioxidant substances may be added to bread to achieve health-promoting effects (Park et al., 1997), while other recipes may enrich the product with dietary fibre (Dalgetty and Byung-Kee, 2006). However, the beneficial nutritional effects of such enrichment do not always correlate positively with the storage stability of bread.

Therefore, the aim of this paper was to investigate the effect of a modified atmosphere (60% CO_2 and 40% N_2) on the quality and shelf life of calcium-enriched wholemeal bread stored at room temperature (20 ± 1 °C). In contrast to bread generally available, such bread shows health-promoting properties due to higher levels of dietary fibre and calcium. The use of principal component analysis (PCA) enabled an evaluation of the interrelations between sensory quality, instrumentally measured textural properties and physicochemical indicators important for the consumer and the baker. Microbiological analyses were also carried out.

2. Experimental material

2.1. Bread making and packaging

Calcium-enriched wholemeal bread was produced under industrial conditions during one shift in a bakery packing bread in a modified atmosphere. The bread was made according to the following dough formulation: 34.7 parts (weight basis) Graham wheat flour type 1850 (according to ash content) containing 11.4% of protein and characterized by 27% wet gluten yield and a falling number value of 210 s; 6.4 rye flour type 720 (6.8% protein, a falling number value of 170 s); 6.2 wheat flour type 750 (11.9% protein, 33% wet gluten and a falling number value of 320 s); 28.0 leaven; 20.0 water; 1.7 whey; 1.2 salt; 1.6 baker's yeast and 0.2 calcium carbonate Calcipur 2 OG with granulometry ≤ 45 μm (90%). The flours were purchased in ZPZ Szymanów, Polskie Młyny (Teresin, Poland); leaven was obtained due to spontaneous fermentation of the rye flour type 720 with water (1:3); whey was provided by a local dairy; baker's yeast originated from the Lesaffre S.A. (Wołczyn, Poland), while calcium carbonate from the Brenntag Sp. z o.o (Kędzierzyn-Koźle, Poland). All ingredients were mixed in a Kemper SP125 spiral mixer (Sispo, Żnin, Poland) for 6 min at low speed (105 rpm) followed by 6 min at higher speed (210 rpm). The resulting dough was left to rise for 90 min at 30 °C and then punched down. After shaping, placing in loaf tins and final fermentation for 40 min at 30 °C, loaves were baked at 200 °C for 45 min in a conventional oven, cooled at room temperature and packed in polyamide/polyethylene bags in a modified atmosphere (60% CO_2, 40% N_2). The bags used fulfilled the EC 90/128/EEC Regulation on materials intended to come into contact with food and were characterized by total thickness of 80 μm and maximum O_2, CO_2 and H_2O permeability of 100 $cm^3/(m^2 \times 24\ h \times bar)$, 140 $cm^3/(m^2 \times 24\ h \times bar)$ and 8 $g/(m^2 \times 24\ h \times bar)$, respectively. The bread was stored in cardboard boxes at room temperature (20 ± 1 °C) for up to 32 days. Samples were examined at regular intervals.

2.2. Sensory evaluation

In the sensory evaluation, each attribute of crumb (taste, smell, and elasticity) and crust (taste, smell, and crispness) was assessed using a 5-point scale (Fik et al., 2000). Each evaluation was carried out by nine panellists appropriately trained and tested for sensory sensitivity. Because of the different relative importance of particular attributes to the overall sensory quality of the product, the following contribution coefficients were used: 0.5 for taste and smell of crumb; 0.2 for taste and smell of crust; 0.2 for crumb elasticity; and 0.1 for crust crispness. In the overall sensory quality assessment, scores of 5, 4, 3, 2 and 1 corresponded to evaluations of very good, good, acceptable, unacceptable, and bad respectively.

2.3. Microbiological analyses

For the microbiological analysis of bread, 10 g of crumb sample was diluted with 90 ml of 0.1% peptone solution and blended for 2 min in a Stomacher 80 (Seward, England). Serial decimal dilutions were made using 0.1% peptone solution. Total aerobic mesophylic bacteria count was determined on plate count agar medium (Karaoglu et al., 2005) after incubation at 30 °C for 72 h. Yeasts and moulds were determined on plates with Sabouraud agar medium, incubated at 25 °C for 3–5 days (Odds, 1991). The levels of vegetative and spore-forming amylolytic aerobic bacteria were assayed on agar medium with starch, according to Waksman (Polish Standard PN-A-74134-4, 1998). In addition, the microbial stability of bread was evaluated by means of thermostat trials (at 30 °C for 30 days), in which samples of bread packed in a modified atmosphere were analyzed in terms of sensory changes resulting from mould growth (Polish Standard PN-A-74102, 1999). Additionally, samples of fresh bread and bread stored in MAP for 3, 6 and 8 days were thermostated at 37 °C for 3 days in Weck jars to investigate changes in the aroma and appearance of the product due to the growth of spore-forming amylolytic aerobic bacteria (Polish Standard PN-A-74102, 1999).

2.4. Textural analysis

Measurements of bread texture were carried out using a TA-XT2 Texture Analyser (Stable Micro Systems, England) coupled with a computer equipped with XT.RA Dimension, v.3.7 software, enabling the instrument to be controlled and data to be processed automatically. Crumb samples (in the form of cubes of 60 mm side) of individual leaves baked from the same batch of dough were subjected to texture profile analysis (TPA) (Breene, 1975; Szczeṡniak, 1963). The samples were compressed twice with an aluminium cylinder-shaped plunger with a diameter of 90 mm to a depth of 36 mm (40% strain). The plunger used moved at a rate of 2 mm/s and the time between strokes was 20 s. The apparatus recorded the force exerted by the plunger as a function of time, from which the following texture parameters were determined: hardness, springiness, cohesiveness and chewiness.

Hardness was defined as the peak force [N] during the first compression cycle. Cohesiveness was calculated as a ratio of areas delimited by the curves of the second and first bite. Springiness was determined as a ratio of the time measured between the start of the second area and the second probe reversal divided by the time measured between the start of the first area and the first probe reversal. Chewiness [N] was assessed by multiplying hardness, cohesiveness and springiness.