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Shelf life assessment of industrial durum wheat bread as a function of packaging system

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ABSTRACT

This study compared the effect of different packaging systems on industrial durum wheat bread shelf-life, with regard to thermoformed packaging (TF) and flow-packaging (FP). Two TFs having different thickness and one FP were compared by assessing physico-chemical and sensorial properties and volatile compounds of sliced bread during 90 days of storage. Texture, a_w and bread moisture varied according to a first-order kinetic model, with FP samples ageing faster than TFs. Sensorial features such as consistency, stale odor, and sour odor, increased their intensity during storage. Furans decreased, whereas hexanal increased. The Principal Component Analysis of the whole dataset pointed out that the TF system at reduced thickness could be adopted up to 60 days, without compromising the standard commercial life of industrial bread and allowing to save packaging material. The FP system would allow further saving, but it should be preferred when the expected product turnover is within 30 days.

1. Introduction

The shelf life of food, defined as the period of time during which quality loss does not exceed a tolerable level, can be decisively influenced by packaging. Bread shelf life is mainly affected by staling, a complex degradative phenomenon which, in turn, depends on starch retrogradation and moisture loss (Bollaín, Angioloni, & Collàr, 2005; Katina, Salmenkallio-Marttila, Partanen, Forssell, & Autio, 2006). Staling results in chemical and physical changes such as decrease of softness and cohesiveness, as well as loss of aroma and flavor (He & Hoseney, 1990).

It is well known that durum wheat bread, especially popular in the Mediterranean area due to its specific sensory and textural properties (Pasqualone, 2012; Quaglia, 1988), undergoes slower staling compared with soft wheat bread, due to high water-binding capacity of durum wheat semolina (Boyacioglu & D'Appolonia, 1994; Hareland & Puhr, 1998; Quaglia, 1988; Rinaldi et al., 2015). The addition of enzymes, such as lipase and amylase, to bread formulation (Bollaín et al., 2005; Giannone et al., 2016; Palacios, Schwarz, & D'Appolonia, 2004), or the use of sourdough (Pasqualone, Summo, Bilancia, & Caponio, 2007; Rinaldi et al., 2015), can further reduce durum wheat bread staling.

Bread staling results in a decrease of consumer acceptance and in great economic losses. As bakery products are becoming a major part of the international food market, the baking industry is undergoing a period of rapid change and modernization, involving the setup of bakery plants with improved technology and new products development (Byrne, 2000). In order to achieve longer shelf lives, refrigerating conditions have been applied to dough, prebaked or not (Rask, 1989; Selomulyo & Zhou, 2007). In addition, new packaging technologies have been investigated.

Packaging is the last step of production and food technologists have to select the most suitable type of packaging to ensure the longest shelf life. The success in the market is equally based on product intrinsic quality and packaging effectiveness in preserving, and communicating, this quality. The conventional packaging procedure applied in baking industry uses atmospheric air and approved lidding materials for foods. However, modern packaging is performed under modified atmosphere and with composite materials specifically formulated in order to retain the inert gases. Several studies evidenced the effectiveness of packaging in

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maintaining the quality characteristics of bread, slowing down moisture loss and molds growth, by using: i) suitable materials (Licciardello, Cipri, & Muratore, 2014; Pagani, Lucisano, Mariotti, & Limbo, 2006); ii) active packaging (Latou, Mexis, Badeka, & Kontominas, 2010; Mihaly Cozmuta et al., 2015); iii) modified atmosphere (Del Nobile, Martoriello, Cavella, Giudici, & Masi, 2003; Piergiovanni & Fava, 1997).

An essential issue in the present day is the selection of packaging systems which are not only effective, i.e. able to maintain quality characteristics, but also efficient, i.e. able to contain environmental impact and costs generated by packaging production and disposal. In a preliminary study, Licciardello et al. (2014) have assessed the feasibility of reducing the thickness of materials used in thermoformed packaging of durum wheat bread, finding that potential gains are possible without compromising the standard shelf life. However, no study has compared the effect of different packaging systems on bread shelf life, with special regard to thermoformed packaging and flow-packaging. Flow-packaging has the advantage of high working speed and could allow further saving of packaging material. The choice of packaging materials is often based on packaging performances, with special regards for gas barrier properties; however, in the case of thermoformed packages, the film properties in the finished product differ from those of the material as received due to thermal stretching, and need to be verified in the conditions of use. Hence, the comparison and choice cannot be made only on the basis of technical sheets available.

The objective of the present study was to evaluate the influence of different packaging systems (namely, one commonly used two-piece thermoformed packaging, a two-piece thermoformed packaging at reduced thickness, and flow-packaging by a very thin material), on quality variations of industrial durum wheat bread by monitoring physico-chemical and sensorial parameters during 90 days of storage.

2. Materials and methods

2.1. Sample preparation

Bread was prepared at a local bread-making company (Valle del Dittaino Società Cooperativa Agricola, Assoro, Italy), according to a consolidated industrial process based on the following formulation: durum wheat remilled semolina, water (66% on semolina basis), compressed yeast (0.47% on semolina basis), NaCl (2.2% on semolina basis), maltogenic α-amylase (0.05% on semolina basis). The ingredients were mixed and kneaded for 17 min by means of a diving arms kneader. The final dough temperature was 26 ± 1 °C. The dough was rested in bulk for 15 min, scaled into 980 ± 20 g portions (100 loaves, repeated for three production trials), proofed for 150 min (32 ± 1 °C and 66 ± 2% RH) and baked at 240 °C for 60 min, in industrial tunnel oven. The baked loaves, weighting approximately 800 g each, were automatically transported to a cooling chamber, set at 20 ± 2 °C for 120 min. After cooling, the loaves were sliced by means of an automatic slicing machine to 11 ± 1 mm thickness.

2.2. Packaging systems

After slicing, portions of 400 g of bread slices were packaged. Three packaging systems were compared; two of them consisted of two-piece packages made up of a thermoformed bottom and a lid. The first packaging system (‘thermoformed 1’ or TF1, commonly used by the baking industry were the trials were carried out) consisted of a 275 μm bottom film and a 125 μm lid; the second was similar to TF1, but with thinner films, 225 μm and 33 μm for bottom and lid, respectively (packaging system ‘thermoformed 2’ or TF2). The third system involved flow-packaging using a 62 μm coextruded film (‘flow-packaging’ or FP). All films were made of multilayered polyolefin materials. An automatic industrial thermoforming machine (MIX 9000, Tecnosistem snc, Coccaglio, Italy) shaped the bottom films for TF1 and TF2 before inserting the sliced bread and sealing with the corresponding lid film, whereas FP was filled and formed by a flow-packaging machine (Jaguar, Record spa, Garbagnate Monastero, Italy). All packaging systems included sprayed ethanol (1.6% on bread weight basis) and modified atmosphere composed of 30% CO_2 and 70% N_2.

The packaging materials were kindly supplied by Cryovac Sealed Air S.r.l. (Passirana di Rho, Italy). Permeability properties, as from the technical sheets of the supplier, were as follows.

O_2 transmission rate (OTR): i) TF1 lid film < 3 g/m^2, 24 h, bar; bottom film = 1 g/m^2, 24 h, bar; ii) TF2 lid film = 4 g/m^2, 24 h, bar; bottom film = 1 g/m^2, 24 h, bar; iii) FP = 4.5 g/m^2, 24 h, bar.

Water vapor transmission rate (WVTR): i) TF1 lid film < 10 g/m^2 24 h; bottom film $\leqslant$ 10 g/m^2, 24 h; ii) TF2 lid and bottom films = not reported; iii) FP = 4 g/m^2, 24 h.

Packaged breads TF1, TF2, and FP were analyzed on the same day of baking (t_0) and after 7, 15, 30, 60, and 90 days of dark storage at 20 ± 1 °C and 55% relative humidity. Three breads ($n = 3$) per each of three packaging systems considered and per each of six sampling times were analyzed, for a total of 54 samples.

2.3. Headspace gas composition analysis

The internal O_2 and CO_2 composition of packages was determined by means of Dansensor Checkpoint portable gas analyzer (Dansensor, Ringsted, Denmark). Ten mL of headspace were analyzed, with three replications.

2.4. Determination of moisture, water activity, alkaline water retention capacity

Moisture content of bread crumb and crust was determined by oven drying at 105 °C until constant weight. Two bread slices (11 ± 1 mm thickness) for each of two repetitions were used, and moisture was determined on one square crumb sample (40 mm × 40 mm) taken from the center of each slice, and on approximately 3 g crust samples manually cut from the same slices. Crumb to crust ratio of breads was 3:1 (w/w). Water activity (a_w) was determined by Hygropalm 40 AW (Rotronic Instruments Ltd, Crawley, UK) according to manufacturers' instructions. Three bread slices (11 ± 1 mm thickness) were used, after removal of the crust. For each set of determinations, separate loaves were considered. Alkaline water retention capacity (AWRC) was determined according to the method described by Yamazaki (1953), conveniently modified for the analysis of bread crumb (Licciardello et al., 2014). Briefly, 1 g of bread crumb, previously dried until constant weight and ground in a mortar, was put in 15-mL tubes (W1), added with 5 mL 0.1 N $NaHCO_3$ and vortexed for 30 s, then let at room temperature for 20 min. The slurry was centrifuged at 3000 rpm for 15 min, the supernatant was discarded and tubes were let drip for 10 min upside down inclined by 15°. Dried tubes were then weighed (W2). AWRC was calculated as [(W2 – W1)/W1] × 100, where W1 is the weight of the tube containing the dry sample and W2 is the weight of the tube containing the dripped sample. Analyses were conducted in duplicate.

Experimental data were fitted to the following first-order kinetic model:

$$C(t) = C^{\infty} + \left(C^{0} - C^{\infty}\right) \cdot \exp(-k \cdot t)$$