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Microstructure, textural and sensorial properties of durum wheat bread as affected by yeast content

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ABSTRACT

In this study, breads varying in yeast content and therefore leading to distinct cellular structures are investigated. Firstly, X-ray microtomography is used to characterize not only the final cellular structure, but also the process of development of microstructure during the fermentation stage. With μCT, image analysis of the full 3-D microstructure, measuring the size, shape, networking/connectivity and distribution of various phases was possible. These measurements represent the full 3-D microstructure, which is not always possible by 2-D image analysis using statistical techniques. Secondly, the textural properties of the baked bread were obtained by compression tests and finally, the sensorial quality of the final product is also evaluated and correlated with the above properties. Results showed that an increase of the yeast content increased the percentage volume of pores and decreased the force required for compression of the bread sample and the tenacity. Moreover, a larger quantity of smaller sized pores led to a firmer bread structure. Regarding the sensorial properties, none of the investigated microstructural parameters were significantly correlated with the overall quality of the bread. In fact, the overall quality was more strongly affected from other parameters such as odor and appearance attributes.

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1. Introduction

The distinctive appeal of bread is in the palatable texture and attractive appearance derived from its aerated structure, made possible by the unique ability of wheat gluten proteins to retain gases produced by yeast fermentation (Campbell, 2003). While the term 'bread' is used generically, there is a wide variety of different types of breads, reflecting local and national culture and practice, and frequently identified by their distinctive aerated structures, or by their specific shapes that the rising process allows the loaf to adopt. In southern Italy bread is commonly produced using durum wheat flour (*Triticum durum*). This type of bread represents a traditional product characterized by higher crumb firmness. As it is well known, bread dough from wheat flour has properties that can differ from each other according to the different water and yeast content. Yeast is the driving force behind fermentation, the process that allows a dense mass of dough to become a well-risen loaf of bread. In bread making, yeast has three major roles. Apart from its well known leavening ability, yeast also helps to strengthen and develop gluten in dough and also contributes to incredible flavors in bread. Yeast works by consuming sugar and excreting carbon dioxide and alcohol as byproducts. Bread making is a process in which large extensional deformation of the dough is featured prominently (Campbell, 2003). During the mixing process, small air cells are incorporated into the dough. These bubbles serve as nucleation sites for the diffusion of carbon dioxide and continue to grow during fermentation and proofing. Bubble growth is affected by four factors; carbon dioxide production, carbon dioxide retention, the rate of CO_2 diffusion from the saturated dough into the nuclei and the rate of bubble coalescence (Shah, Campbell, McKee, & Rielly, 1998). Bread dough exhibits extremely complex rheological properties that impact bubble structure and size distribution and overall stability. The ability of the gas cells to resist failure and remain stable throughout the proofing and baking process is critical to final bread texture and volume.

Bread relies on its cellular foam structure for value and functionality. Breadcrumb is usually defined as a spongy porous material characterized by both closed and open pores. Each bread sample can differ in porosity and the cells can have different dimensions, shapes, orientation and connectivity. These microstructural parameters have to be measured for a quantitative description of breadcrumb microstructure as the knowledge about the microstructure of foods can be used to identify the important processing parameters that affect the quality of a product and Pyler (1988), stated that the crumb texture is greatly influenced by the cell structure of the crumb. The microstructure of food products influences to a large extent the physical, textural and sensory properties of these products. Developing a proper understanding of the microstructure, particularly the spatial distribution and interaction of food components, is a key tool in developing products with desired mechanical and organoleptic properties. The result of baking is a structure defined by a relatively solid outer

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crust and a soft, delicate crumb comprising cell walls that surround gas cells and determine the mechanical properties of the loaf. The internal and external appearance, compressibility and fracture mechanics of the loaf are key factors determining its aesthetic appeal, apparent freshness and performance during consumer handling. The mechanical properties of baked crumb structures of both bread and cakes have been vastly studied under compression or tension or both by Chen, Whitney, and Peleg (1994), Swyngedau and Peleg (1992). Promising results based on the material science of cellular foams have been reported (Liu & Scanlon, 2002; Scanlon, Fahloul, & Sapirstein, 1997; Scanlon, Sapirstein, & Fahloul, 2000; Zghal, Scanlon, & Sapirstein, 2001), in which mechanical properties such as Young's modulus and critical fracture stress have been related to structure.

The sensory property of bread, which is still a challenge, requires a better understanding of relationships between composition, cellular structure formation mechanisms and final texture. It is well known that for texture, sensory properties of solid food foams are related to both mechanical properties and cellular structure (Pyler, 1988). In this context, determining the relationships between a given mechanical property and the cellular structure is thus of prime importance. It is worth noting that, there are no studies dealing the effect of the yeast content on the microstructure, textural and sensorial properties of durum wheat bread and their correlations.

In this study, breads varying only in yeast content and therefore leading to distinct cellular structures are investigated. Firstly, X-ray microtomography is used to characterize not only the final cellular structure, but also the process of development of microstructure during the fermentation stage. Secondly, the textural properties of the baked bread are obtained by compression tests and finally, the sensorial quality of the final product is also evaluated and correlated with the above properties.

2. Materials and methods

2.1. Raw materials

Durum wheat flour was supplied from Tandoi mill (Corato, Bari, Italy), fresh compressed yeast and salt were purchased from a local market, whereas dried sourdough was supplied from Bongiovanni mill (Villanova Mondovi', Cuneo, Italy).

2.2. Breadmaking process

Dough mixing, processing and baking were performed on laboratory-scale equipment. A double dough fermentation process was used. The dough based on durum wheat (100%) was obtained with a pre-mixture of 2.9 L of water, 100 g of salt, 1.5 kg of flour and 100 mL of extra virgin olive oil stirred at high speed for 10 min in a mixer (Conti, Bussolengo, Verona, Italy). Once a homogeneous mixture was obtained, it was transferred in a mixer with a higher capacity (Bernardi Impastatrici, Cuneo, Italy). At this point yeast, 100 g of dry sourdough and 3.0 kg of durum wheat flour were added and mixed at the average speed for 25 min. The amounts of yeast used to make the bread are the following: 20 g (sample Br-y20), 50 g (sample Br-y50), 100 g (sample Br-y100), 300 g (sample Br-y300), 400 g (sample Br-y400), 500 g (sample Br-y500). Afterwards, the dough was left to rest for 15 min before adding more 100 mL of extra virgin olive oil. After complete mixing, the dough rested in bulk in the incubator (Thermogel, Varese, Italy) for a time of 15 min, at a temperature of 30 °C and 85% of relative humidity. Subsequently, portions of 1500 g were made, they were manually rounded and placed above a baking tray in the incubator at the same conditions, for the final fermentation lasting 75 min. Following fermentation, the samples were baked at 270 °C for 55 min in an electric oven (Europa Forni, Vicenza, Italy).

2.3. Tomographic analysis

In this study the microstructure properties of dough and bread samples were determined using a Skyscan 1172 high-resolution desktop X-ray microtomography system (Skyscan, Belgium). The bread samples were cylindrical in shape and diameter of 2.8 cm. Whereas the dough samples, each weighing 1.5 g, were analyzed at two different times of leavening (30 and 105 min). In particular, immediately after the leavening period the dough samples were put in a cooling cell at 4 °C for 20 min in order to stop the fermentation process during scanning. Five replicates were carried out for each sample and all samples were imaged as follows; each sample was placed on a rational plate; the source and the detector were fixed, while the sample was rotated during measurement, a CCD camera with 2000×1048 pixels equipped with power settings of 59 kV and 94 μA was used. The distance source–object–camera was adjusted to produce images with a pixel size of 2 μm. Two-frame averaging, a rotation step of 0.70° and an exposure time of 590 ms were chosen to minimize the noise, covering a view of 360°. Each scanning required an average of 20 min. A set of flat cross section images was obtained for each sample after tomographical reconstruction by the reconstruction software NRecon (Skyscan). Three-dimensional reconstructions of samples were created by effectively stacking all 2D tomographs, a total of 125 slice images with a slice spacing of 0.069 mm.

For image processing and data analysis, the skyscan software, CT-Analyzer (CTAn) was used. Image segmentation was firstly carried out on the smoothed 8-bit grey-scale images obtained from the reconstruction step, using CTAn (Skyscan) software. Segmentation is the process of converting the grey-scale images into black and white images by assigning the value 1 to all pixels whose intensity was below a given grey tone value and 0 to all the others. For this, an automatic threshold based on the entropy of the histogram (Sahoo et al., 1997) was calculated for each image. The lower grey threshold (8) and upper grey threshold (110) values were identified; each sample was processed under the same conditions. The following five geometric parameters were measured using the CTAn software (Skyscan): percent object volume (POV), object surface/volume ratio (OSVR), fragmentation index (FI), degree of anisotropy (DA) and structure modeling index (SMI). Where, i) POV is the proportion of the VOI (volume of interest) occupied by void areas, i.e. holes; ii) OSVR is the basic parameter in characterizing the complexity of the structures and is also the basis of model-dependent estimates of thickness i.e. size and distribution of holes present in each sample; iii) FI is an index of connectivity of structure, which was developed and defined by Hahn et al. (1992), it calculates the index of relative convexity or concavity of the total surface of the sample; iv) DA is a measure of the preferential alignment of the structure under investigation, i.e. pores and finally; v) SMI estimates the characteristic form of which the structure is composed, i.e. whether it is more plate-like, rod-like or even sphere-like ($0 =$ ideal plate, $3 =$ cylinder and $4 =$ sphere).

2.4. Bread compression analysis

Bread sample firmness was determined instrumentally by means of compression test using a Zwick/Roell model Z010 texture analyzer (Zwick Roell Italia S.r.l., Genova, Italy). Cylindrical breadcrumb aliquots were placed between the parallel plates: an insert plate fixed in the universal work platform ($100 \times 90 \times 9$ mm) and a compression die (75 mm diameter). The force required to compress slices of bread to a predetermined level of penetration against a rigid back plate using a cylindrical plunger was recorded for each sample tested. All bread loaves were uniformly sliced to a thickness of 15 mm by using an electric slicing knife (Ariete SL2045, Italy) that avoided crushing the sample. Crumb samples with cylindrical in shape (28 mm diameter) were cut from the center of each bread loaf using a circular cutter. Trial specifications were as follows: pre-load of 0.3 N; load cell of

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