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Rheological, microstructural and sensorial properties of durum wheat bread as affected by dough water content

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ABSTRACT

In this paper the influence of water content on the rheological, microstructural and sensorial properties of durum wheat bread was evaluated. In order to evaluate bread quality, oscillation measurements, stress relaxation test and creep–recovery measurements were performed on dough samples, whereas tomographic and sensorial analyses were performed on baked bread samples. Results of the rheological analysis highlighted that both the storage and loss moduli (G', G'') showed a descending trend with the increase of the water content. This is also confirmed by stress relaxation tests. Creep–recovery tests for strong doughs (with low water content), recorded greater resistance to deformation, therefore a smaller creep strain than the softer doughs. These results were reflected in the microstructural properties of the bread; an increase in water content caused an increase in the percentage volume of pores. Regarding the sensorial properties, the overall acceptability of the investigated bread samples was low for both the lowest and the highest water contents, and this was due primarily to the compact crumb with small bubbles and high crust firmness for the former and to the loaf volume collapsed with irregular distribution of very large bubbles for the latter. Therefore, the bread samples with intermediate water content were preferred by the panelists.

1. Introduction

Bread is considered to be of global importance in nutrition being a source of proteins, dietary fibers, vitamins, micronutrients and antioxidants. Unlike other areas of the world, in southern Italy bread is commonly produced using durum wheat flour (*Triticum durum*). This type of bread represents a traditional product characterized by a higher crumb firmness, a lower loaf volume and a longer shelf-life compared to wheat bread (Boyacioglu & D'Appolonia, 1994).

It is well known that wheat flour dough is a heterogeneous system in which starch granules are included in a gluten network. The wheat gluten proteins correspond to the major storage proteins that are deposited in the starchy endosperm cells of the developing grain. These form a continuous proteinaceous matrix in the cells of the mature dry grain and are brought together to form a continuous viscoelastic network when flour is mixed with water to form dough (Angioloni & Collar, 2009). In making dough, water is an essential ingredient; in fact, it is needed to form the gluten and give the dough consistency. In particular, the consistency depends clearly on the amount of water used in making it. The water added to the flour fulfills four functions: it dissolves soluble molecules, activates enzymes, brings about the formation of new bonds between the macromolecules in the flour, and alters the rheological properties of the dough. The large amount of water that is added to the flour has to be absorbed by the flour polymers. The majority of the water added to make up the dough is absorbed by hydrophilic groups on the protein molecules. If the water is insufficient for the hydration of all dough ingredients, the gluten does not become fully hydrated and the elastic nature of the dough does not become fully developed. Conversely, an excessive level of free water in the dough results in the domination of the viscous component of dough, with a decreased resistance to extension, increased extensibility and the development of sticky dough (Spies, 1997). The potential role of an aqueous liquid phase in doughs is to stabilize the surface active materials at the gas–liquid interface, to maintain the integrity of gas bubbles and to promote gas retention. Moreover, the amount of free water is also likely to determine the type and quantity of material that may become solubilized during mixing and dough development.

Varying the amount of water can modify the microstructure of the dough. Water is considered to play the most important role in the viscoelastic properties of dough due to its influence on the development of the gluten protein network (Skendi, Papageorgiou, & Biliaderis, 2010). Crumb cellular structure (or its grain) is an important quality criterion used in commercial baking and research laboratories to judge bread quality alongside taste, crumb color and crumb physical texture. Umbach, Davis, Gordon, and Callaghan (1992) found a higher diffusion coefficient of water molecules in starch–water mixtures than in gluten–

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water mixtures before heating. It was concluded that small amounts of water in dry starch were very tightly associated, but additional water did not interact with starch, thus remaining quite mobile. Once further hydrated, water in gluten led to more water–protein interaction, thus becoming more immobile. Experimental studies using the aqueous phase of dough to furnish the required water in breadmaking gave beneficial effects on loaf volume and crust color (Baker, Parker, & Mize, 1946). It was shown that a lower loaf volume was obtained when the dough was deprived of its aqueous phase, and this affected gas retention (MacRitchie, 1976). Letang, Piau, and Verdier (1999) have already shown that the microstructure is essential to compare the evolution of different doughs based on soft wheat flour. It can be seen as the linkage between the ingredients and the apparent macroscopic properties of the final product.

However, the majority of the studies reported in literature based on the water–dough relation referred to soft wheat flour mixed with water. There are no studies dealing with the effect of dough water content on durum wheat flour bread. In addition, results from the literature are qualitatively interesting, but each flour is different and general quantitative interpretations are difficult. This work proposes to study the influence of water content on the process parameters of durum wheat flour doughs and bread by relating the microstructure to the rheological and sensorial properties. This approach allows giving an interpretation of the evolution of dough properties in terms of microstructural changes.

The aim of this work was to evaluate the influence of dough water content on the dough's rheological, microstructural and sensorial properties of durum wheat bread. Oscillation measurements, stress relaxation test and creep–recovery analysis were performed in order to evaluate the rheological behavior of the different doughs. Moreover, tomographic analysis was carried out to evaluate the texture properties of the manufactured bread. Finally, the sensorial quality of the final product was also evaluated and correlated with some of 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, and dried sourdough was supplied from Bongiovanni mill (Villanova Mondovi', Cuneo, Italy). The amount of tap water used to make bread varied according to Table 1.

2.2. Breadmaking process

A basic bread formula consisting of durum wheat flour (4500 g), fresh compressed yeast (100 g), salt (100 g), dried sourdough (100 g) and tap water (Table 1) was used. Dough mixing, processing and baking were performed on laboratory-scale equipment. A straight dough process was used. All dry ingredients were mixed thoroughly with half of water in a mixer (Bernardi Impastatrici, Cuneo, Italy) at high speed (120 rpm) for 10 min, and then the rest of the water was added slowly and mixed for 15 min (4 rpm). After complete mixing, the dough rested in bulk for a period of 15 min, then portions of 1500 g were made, manually rounded and put into canvas for the final fermentation. The portions are put in the incubator (Thermogel, Varese, Italy) for 60 min, at 26 °C of temperature and 65% of relative humidity.

Following fermentation, the samples were baked at 270 °C for 55 min in an electric oven (Europa Forni, Vicenza, Italy).

2.3. Dough rheological properties

2.3.1. Oscillation measurements

Dough samples for the rheological tests were prepared without adding any yeast to the formulation to avoid bubble interference. The rheological measurements were conducted using a controlled-strain rotational rheometer (ARES model, TA Instruments, New Castle, DE) equipped with a force rebalance transducer (model 1K-FRTN1, 1–1000 g cm, 200 rad/s, 2–2000 gmf) and parallel plates (superior plate diameter of 50 mm). A steady temperature was ensured with an accuracy of ±0.1 °C by means of a controlled fluid bath unit and an external thermostatic bath.

Before starting the measurement, a sample taken from the inside of the dough, was rested between the plates for 5 min, so that the residual stresses would relax (Amemiya & Menjivar, 1992; Letang et al., 1999). Each type of dough was placed onto the surface of the lower plate and the upper plate was lowered until it reached a 2 mm gap distance as to avoid sample disruption and the excess sample was trimmed. Slippage was prevented by using sandpaper.

To prevent water evaporation, a suitable cover tool sealing the top of the superior plate was used during testing. In fact, the dehydration leads to crusting, which affects the results significantly (Szczesniak, Loh, & Wesley, 1983). Storage modulus (G'), loss modulus (G'') and loss tangent ($\tan\delta = G''/G'$) were determined in a frequency range of 0.05 to 10 Hz in the linear viscoelastic region. As an example, the storage and loss moduli, G' and G'', as functions of the frequency taken in the linear viscoelastic region are shown in Fig. 1A. The strain value was obtained by preliminary strain sweep oscillatory trials to determine the linear viscoelastic region. The strain sweep oscillatory tests were carried out at a frequency of 1 Hz and in a range of shear strain of 0.01 to 300%. The linear domain was found to be very small, the linear strain limit being around 0.02–0.065%.

All experiments were carried out at 25 °C. Three repetitions of the dynamic mechanical experiments were performed for each dough sample. To compare the G' and G'' values between the investigated dough samples an oscillatory frequency of 10 Hz was chosen as a reference (Dimitreli & Thomareis, 2008).

2.3.2. Stress relaxation tests

Mechanical transient tests were performed to evaluate the spectrum of the relaxation times from relaxation curves. Fig. 1B highlights an example of stress plotted as a function of decay time in a stress

Table 1
Levels of the experimental design used for bread-making process, and parameters of the stress relaxation and creep analysis for dough samples.

	Water content (%)	$\tan\delta$	$1/\sigma_0$ (1/MPa)	m	λ (s)	K (1/MPa)	Maximum creep strain (%)	Maximum recovery strain* (%)	Relative recovery strain** (%)
Br-w54	54.44	$0.31^{a} \pm 0.005$	17.65^{a}	1.01^{a}	$1.16e\text{-}2^{a}$	0.85^{a}	$7.83^{a} \pm 0.27$	3.49	224.35
Br-w57	57.77	$0.48^{b} \pm 0.05$	9.48^{b}	1.01^{a}	$1.2e\text{-}2^{a}$	0.85^{a}	$9.71^{a} \pm 2.9$	3.22	301.55
Br-w61	61.11	$0.43^{b} \pm 0.01$	12.93^{c}	1.01^{a}	$1.18e\text{-}2^{a}$	0.85^{a}	$9.74^{a} \pm 1.9$	3.35	290.74
Br-w64	64.44	$0.46^{b,c} \pm 0.05$	4.18^{d}	1.02^{a}	$2.00e\text{-}2^{b}$	0.73^{b}	$44.88^{a} \pm 20.1$	26.00	172.61
Br-w67	67.77	$0.46^{b,c} \pm 0.01$	5.07^{d}	0.13^{b}	$9.94e\text{-}3^{a}$	0.42^{c}	$106.86^{b} \pm 3.15$	40.43	264.31
Br-w71	71.11	$0.46^{b,c} \pm 0.02$	2.43^{e}	0.67^{c}	$3.13e\text{-}2^{c}$	0.30^{d}	$214.46^{c} \pm 26.5$	68.78	311.81
Br-w74	74.44	$0.5^{c} \pm 0.02$	1.23^{f}	0.81^{c}	$3.76e\text{-}2^{c}$	0.15^{e}	$679.92^{d} \pm 80.8$	109.88	618.78

[a–f] Mean in the same column followed by different superscript letters differs significantly ($p<0.05$).

[*] Calculated as: [maximum creep strain − steady recovery].

[**] Calculated as: [maximum creep strain / maximum recovery strain * 100].