Food Research International 43 (2010) 2315–2320

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Effect of pentosan addition on dough rheological properties

Massimo Migliori, Domenico Gabriele *

Department of Engineering Modelling, University of Calabria, Via P. Bucci, Cubo 39C, I 87030 Rende (CS), Italy

ARTICLE INFO

Article history:
Received 13 May 2010
Accepted 6 August 2010

Keywords:
Rheological models
Oscillatory measurements
Transient test
Stress relaxation
Nonlinear behaviour

ABSTRACT

In this paper a complete rheological characterisation of bread dough added with water-solvable pentosans is showed. In the literature several works are available showing the chemical and physical effect of pentosan addition but it is still matter of discussion of their effect on the mechanical properties of dough. Therefore, the main objective is to further study this point, evaluating the effect of pentosans on the rheological properties of dough, using fundamental measurements and rheological modelling. Small amplitude oscillations at different temperatures were performed to evaluate material properties and stress relaxation tests, either within or out of the linear range, were used to investigate the effect of large deformations on material structure. Results showed that the effect of the addition is variable, depending on the amount, type of pentosans and deformation amplitude. The obtained results, together with rheological modelling, allow either to design dough having controlled properties during critical manufacturing steps (e.g. leavening or baking) or to reduce mechanical properties variability as effect of natural variation in flour characteristics.

1. Introduction

Flour based products are always requested by consumers and their demand is sharply increased during the last decade. This phenomenon, apart from normal market increase, is basically due to new trend of flour manufacturers that are increasing the offer of "special flours" particularly designed for specific application such as: home-made bread, pizza, spongy cakes, biscuits, and "self-leavening" flour. According to the craft-made preparation process and the specific recipe characteristics (e.g.: vegetable fats, sugar, raising agent addition) the flour should be able to guarantee in any condition the desired performance, even though in-home facilities are strongly different from the industrial one. In this concern researchers have to look into two different problems: either to design the specific flour composition in order to get the expected performance or to guarantee constant flour characteristics time to time, tackling natural flour composition changes. In this concern the addition of natural additives, obtained either by different flour fractions or by different vegetal sources, may play a crucial role helping in control flour characteristics (Fustier, Castaigne, Turgeon, & Biliaderis, 2008; Fustier, Castaigne, Turgeon, & Biliaderis, 2009; Paraskevopoulou, Provatidou, Tsotsiou, & Kiosseoglou, 2010; Skendi, Biliaderis, Papageorgiou, & Izydorczyk, 2010). Water soluble pentosans (WSP) and unextractable solids (WUS) are the major nonstarch component of flour, being mostly based on hemicellulose (Yin & Walker, 1990) and their role, as functional ingredients, is well known (D'Appolonia & Gilles, 1971; Michniewicz, Biliaderis, & Bushuk, 1991). Very extensive chemical investigations of water soluble (WSP) and insoluble (WIP) pentosans are available, even though different explanations still hold about their ability in conditioning rheological properties of dough (Denli & Ercan, 2001; Wang, van Vliet, & Hamer, 2004a). A very accurate description of the status of the art about pentosan (and xylanase) effect on dough is proposed by Wang et al. (2004a) and the same authors also identified that water affinity change due to pentosan presence is driven both by chemical and physical effect (Wang, van Vliet, & Hamer, 2004b). In this series of paper, a rheological characterisation at room temperature (Wang et al., 2003), is applied to different mixtures of glutenin macro-polymer (GMP) and pentosans, in order to quantify mechanical impact of the addition, showing that WSP affect GMP rheological properties and the effect can be adapted to the desired value by changing water content and/or mechanical energy input. The authors also showed that WSP treated under freeze-drying conditions did not exhibit any significant difference when compared with non-dried one. This represents valuable information because, in the view of industrial application, the effect of storage conditions and technique on pentosan activity has to be clearly understood.

The effects of soluble and insoluble pentosans on breadmaking were examined measuring specific volume and staling of breads (Maeda & Norita, 2003) prepared by flours from polishing wheat grain. Positive results, in terms of increase in loaf volume and retarded firmness, were obtained for both types of pentosans, even though larger amount of WIP than WSP seems necessary to obtain good baking characteristics. The quality improvement caused by WSP was attributed by the authors to their viscous and gelling properties that improve the strength of gluten network and, as a consequence, the gas retention (Maeda & Norita, 2003).

* Corresponding author. Tel.: +39 0984 496687; fax +39 0984 494009.
E-mail addresses: migliori@unical.it (M. Migliori), d.gabriele@unical.it (D. Gabriele).

0963-9969/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodres.2010.08.008

In this paper the characterisation of standard flour added with WSP is presented, aiming to investigate the effect of temperature and WSP amount on the rheological characteristics of dough by performing a more extensive fundamental characterisation also using transient experiment. In addition the effect of one WSP storage technique is investigated by analysing performance of WSP treated using a spray drying process, in order to increase the storage time.

2. Materials and methods

Samples were prepared by using commercial flour for breadmaking and pentosans kindly supplied by IPALC (Italy). In order to check the effect of the dehydration process on the pentosan activity, the starting solution was also spray dried and the same type of pentosans were supplied by IPALC in two different ways: the original water solution and the powder obtained by spray drying the solution.

Water content of either flour and pentosans was determined by using an halogen moisture analyzer (HB43, Mettler Toledo, Germany) set at 130 °C and recording the final moisture (on wet basis) when weight loss rate was lower than 1 mg/140 mg.

A moisture of 12.6 ± 0.4% (w/w) was determined for flour, whilst a solid content of 6.8 ± 0.2% (w/w) was obtained for the pentosan solution and the powder moisture was found lower than 5%.

2.1. Sample preparation

The reference sample (B sample), including only flour and water in a mass ratio of 2:1, was modified adding pentosans from both sources and keeping a constant weigh ratio (1:100 or 1.5:100) between pentosans and flour. When the solution was used, the proper amount was computed, on the basis of the determined solid content, to keep the desired pentosans to flour ratio. When pentosans in powder were tested, because of the small amount of powder added to the flour, the water coming from the powder was neglected when changing the recipe. Three samples were obtained and details on their composition are reported in Table 1.

Dough was prepared by mixing ingredients in a lab scale mixer (Hobart, UK) equipped with a flat beater (B type, Hobart, UK) and keeping 5 min as constant mixing time. Temperature of the mixing bowl was controlled by circulating water at 30 °C in an external jacket. After mixing, dough slabs were prepared by using a commercial hand-roller machine (Imperia, Italy), the sheeting procedure was standardised and after six pass through rollers (decreasing the nip), a final thickness of approximately 2 mm was obtained. In order to relax sheeting-induced stresses, samples were stored in aluminium foil for 20 min at room temperature before starting the rheological characterisation. No water loss was measured during this storage period.

2.2. Rheological characterisation

Rheological characterisation of dough has been performed using either a controlled stress rheometer (DSR200, Rheometric Scientific, USA) for small amplitude oscillation test or a controlling strain rheometer (ARES-RFS, TA Instruments, USA) for transient stress relaxation tests. Both instruments were equipped with parallel plate geometry (ϕ = 25 mm) and temperature control was ensured by a Peltier system acting under the lower plate. Potential slippage in nonlinear viscoelastic conditions was eliminated by applying commercial adhesive-backed sandpaper (grit P40) on surfaces of either the Peltier plate or the upper plate tool. A constant gap of 2.2 ± 0.1 mm was kept during all tests.

Table 1
Sample composition.

Ingredient	Sample ID			
	B	1%P	1%S	1.5%S
Flour (g)	500	500	500.0	500.0
Water (g)	250	250	181.5	147.2
Pentosan powder (g)	–	5	–	–
Pentosan solution (g)	–		73.5	110.3

Oscillatory tests included stress sweep test at the fixed frequency of 1 Hz performed at different temperatures (30 °C, 50 °C, 70 °C and 90 °C), in order to found the linear viscoelastic region of the material. At the investigated temperatures, frequency sweep tests were carried out, in linear conditions, in the frequency range 0.1–10 Hz. Even though lower frequencies are often used in material characterization to yield information on long relaxation processes, according to the rheological model adopted in the present paper to describe dough behaviour, the 0.1–10 Hz frequency range was considered adequate to fully describe the rheological behaviour of tested samples.

Dynamic characterization was completed by a temperature ramp test (time cure) at 1 Hz, in linear viscoelastic conditions, increasing temperature from 25 °C to 100 °C at 1 °C/min.

Transient tests were performed either within or out of the linear viscoelastic range of strain (Keentok, Newberry, Gras, Bekes, & Tanner, 2002; Uthayakumaran, Newberry, Phan-Thien, & Tanner, 2002) imposing two different strain: 0.04% (typical value for linear viscoelastic range determined by strain sweep tests) and 4%, well out of the linear region, in order to study mechanical behaviour under large deformation. It was not possible to carry out transient tests in nonlinear conditions at high temperature because the increase in dough consistency, caused by the starch gelatinization, requires torque values above the rheometer upper limit (maximum torque 0.1 N m). Therefore, stress relaxations, both within and out of the linear conditions, were carried out only at 30 °C and 50 °C.

During all tests water loss was reduced by covering the sample rim with a silicon oil (Silicon oil DC, Fluka, Italy) having a viscosity enough low (300 mPa s), if compared with dough consistency, to avoid any effect on the test results.

All the tests were performed on three independent preparations and a good reproducibility was found; experimental data are shown in terms of average value and standard deviation (always lower than 5.0%).

2.3. Rheological data analysis

According to literature (Phan-Thien, Safari-Ardi, & Morales-Patino, 1997; Uthayakumaran et al., 2002) dough exhibits mainly a solid-like behaviour as confirmed by the absence of a real steady state shear viscosity. Any attempt to measure viscosity, in a transient test at constant shear rate, ended up to a continuous decrease of the viscosity without any steady viscosity plateau. This problem was faced by some authors (Phan-Thien et al., 1997) that also recognised the exigency to use for dough a "solid-like" constitutive equation. A solid-like approach, recently proposed, is based on the observation that dough, such as many other foods, exhibits a critical gel behaviour (Gabriele, D'Antona, & de Cindio, 2001; Ng & McKinley, 2008; Ng, McKinley, & Padmanabhan, 2006). This approach, originally proposed to describe the linear viscoelastic behaviour in dynamic tests (Gabriele et al., 2001) has also been used to describe other types of deformation, including stress relaxation in linear and nonlinear conditions for gluten dough (Ng & McKinley, 2008).

According to this literature, rheological properties of dough have been interpreted considering it as a solid behaving as a "weak gel" in the investigated frequency range (Gabriele et al., 2001). The proposed model includes the prediction of a linear behaviour in a double-log plot of the dynamic moduli vs the frequency and, referring to complex modulus G^*, data can be fitted using a two parameter power law:

$$G^*(\omega) = \sqrt{G'^2 + G''^2} = A \cdot \omega^{\frac{1}{z}} \quad (1)$$