LWT - Food Science and Technology 88 (2018) 159–164

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Rheological properties and baking performance of new waxy lines: Strengths and weaknesses

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ARTICLE INFO

Article history:
Received 3 June 2017
Received in revised form
2 August 2017
Accepted 24 September 2017
Available online 25 September 2017

Keywords:
Waxy wheat
Stickiness
Dough rheology
Bread-making

ABSTRACT

In Western countries, the use of waxy wheat in bread-making is gaining interest in view of extending the shelf-life of bread, avoiding the use of additives. Considering the high impact of the environment on wheat properties, selection of waxy lines able to adapt to a particular environment is highly recommended. In this frame, the behavior of three new Italian waxy lines (IW) were compared with that of two waxy lines breeded in United States (USW). Compared to USW, two out of three IW lines exhibited better mixing properties in terms of higher tolerance to mechanical stress (stability and softness index). IW dough showed similar water absorption, stickiness values and visco-elasticity (G′ and G″) compared to USW samples. On the other hand, the waxy wheat lines adapted to the Italian environmental conditions showed a more developed loaf volume with respect to USW lines. The difficulties in dough handling that is typical of waxy wheat when used alone could be partially solved using waxy wheat in combination with non-waxy flours.

1. Introduction

Waxy (or amylose-free) wheat is characterized by low amylose content - generally < 3 g/100 g (Van Hung, Maeda, & Morita, 2007) - due to the absence of all the three isoforms of the granule-bound starch synthase (GBSS-I), which are responsible for the biosynthesis of amylose (Sivak & Preiss, 1995).

Starch retrogradation is believed to be one of the major players of the increase in bread crumb firmness during storage, commonly referred to as bread staling, and amylose is assumed to be the main contributor to this phenomenon during the first hours after baking (Van Hung et al., 2007). Thus, food industry is increasingly interested in waxy starch and in its low susceptibility to retrogradation (Šárka & Dvořáček, 2017). Indeed, the use of waxy wheat in the formulation would avoid the addition of the additives commonly used in bread-making (e.g. enzymes, emulsifiers, etc.) to extend the shelf-life of baked products (Šárka & Dvořáček, 2017). The unique properties and uses of waxy wheat in noodles, bread, cakes, tortillas, refrigerate and frozen food products have been widely reviewed (Graybosch, 1998; Hayakawa, Tanaka, Nakamura, Endo, & Hoshino, 2004; Šárka & Dvořáček, 2017; Van Hung, Maeda, & Morita, 2006; Yi, Kerr, & Johnson, 2009).

Japanese researchers were the first to produce completely waxy wheat (Nakamura, Yamamori, Hirano, Hidaka, & Nagamine, 1995). Since then, numerous efforts to develop waxy wheat cultivars are underway in Europe, United States, and Australia (Graybosch, 1998). Considering the high influence of the environment on wheat productivity and quality (Graybosch, Souza, Berzonsky, Baenziger, & Chung, 2003), it is unlikely that waxy wheat lines produced in United States or Japan could be successfully cultivated in other countries. Moreover, consumer resistance and existing regulations do not allow employing genetically engineered foods in Europe. For these reasons, waxy wheat obtained from traditional crossing starting from partial waxy autochthonous landraces have to be taken into consideration (Boggini, Cattaneo, Paganoni, & Vaccino, 2001).

In the perspective of developing waxy wheat lines suitable for being cultivated in the Mediterranean area, various research activities have been accomplished in the past decade (Boggini et al., 2001; Monari, Simeone, Urbano, Margiotta, & Lafiandra, 2005;

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https://doi.org/10.1016/j.lwt.2017.09.035
0023-6438/

Urbano, Margiotta, Colaprico, & Lafiandra, 2002). In particular, a breeding program involved partial-waxy cultivars previously identified in the germplasm collection, leading to the release of 18 waxy lines (Boggini et al., 2001; Caramanico, Vaccino, & Pagani, 2011). Out of these lines, three were worthy of consideration for being proposed for registration based on their agronomic performance (Caramanico et al., 2011). In this context, the aims of the present work were to: i) evaluate dough rheological properties and bread-making performance of the three Italian waxy lines and ii) compare our waxy lines with two waxy lines from United States with similar compositional traits.

2. Materials and methods

2.1. Materials

Five waxy wheat lines were used in this study: three Italian waxy wheat lines (henceforth IW), and two US waxy lines (henceforth USW; Morris & Konzak, 2001). IW lines were obtained by mating F1 offsprings from the cross between two partial-waxy cultivars identified in Italian germplasm (Cologna lunga, Wx-D1, and Barra, Wx-B1) with the US lines. IW_70 and USW_546 were characterized by hard kernel texture, IW_123 by medium hardness, while IW_118 and USW_545 by soft texture.

All the samples were grown in S. Angelo Lodigiano (Italy) during the 2009-10 growing season. Wheat kernels were milled into flour (particle size less than 220 nm) in a Bona Quadrumat Labor mill (Bona, Monza, Italy).

A non-waxy wheat flour (Aubusson cv.; henceforth NWW; protein: 10.8 g/100 g; alveographic W: 155 $^*10^{-4}$ J; alveographic P/L: 0.56) was used as reference. This variety has been chosen because its alveographic indices were similar to those of the USW lines (data not shown).

Moisture, starch, protein, fat, and ash content was determined according to the approved methods AACC 44-15A, 76-13, 39-10 and 46-12, 30-10, 08-12, respectively (AACC, 2000). In particular, protein content was determined by using the NIR System Model 6500 (Foss NIR Systems, Laurel, MD). Amylose content was measured by enzymatic kit Megazyme International (Megazyme International Ireland Ltd., Wicklow, Ireland) and expressed as g/100 g starch. Gluten Index was measured according to the AACC 38-12 method (AACC, 2000).

2.2. Pasting properties

The pasting properties of flours were determined by using the Rapid Visco Analyzer test (RVA-4 model, Newport Scientific, Sidney, Australia), according to the approved method ICC 162 (ICC, 1992). An aliquot of flour (3.5 g) was dispersed in distilled water (25 mL), scaling both sample and water weight on a 14 g/100 g sample moisture basis. The suspension was subjected to the following temperature profile: holding at 50 °C for 1 min; heating from 50 to 95 °C; holding at 95 °C for 3.5 min; cooling from 95 °C to 50 °C; holding at 50 °C for 2 min. A heating/cooling rate of 12 °C/min was applied. Data were processed by using the software provided with the instrument (Thermocline for Windows, rev. 3.6). Measurements were performed in triplicate and the average value was used.

2.3. Viscoelastic properties

The fundamental rheological behavior of dough samples was studied by dynamic oscillatory measurements performed on a Physica MCR300 Rheometer (Anton Paar GmbH, Graz, Austria), supported by the Universal Software US200 (version 2.5) (Anton Paar, Ostfildern, Germany).

Dough sample was prepared by mixing flour (10 g) and water (according to the water absorption calculated by the farinograph test) for 1 min in the Glutomatic 2200 (Perten Instruments, Stockholm, Sweden). Measurements were carried out at 25 °C, using a corrugated plate system (diameter: 2.5 cm) at a gap of 1 mm. After loading the sample between the parallel plates, the excess was trimmed off and a thin layer of paraffin oil was applied to the edge of the exposed sample to prevent moisture loss during measurements Sample was allowed to rest at 25 °C for 30 min to relax stresses, before starting the test.

Dynamic shear data were measured within the linear viscoelastic region, as determined by preliminary amplitude sweep tests performed in the range of 0.01–200% strain, at a constant frequency of 1 Hz. Frequency sweep tests were performed over the range 0.1–10 Hz at 0.03% strain. From each trial, storage modulus (G′, Pa) loss modulus (G″, Pa), and tanδ (ratio between G″ and G′) were computed by using US200/32 v.2.50 rheometer software (Physica Messtechnic GmbH, Ostfildern, Germany). All the measurements were performed in triplicate.

2.4. Mixing properties and stickiness

Mixing properties were evaluated in triplicate using the Brabender Farinograph-E (Brabender OHG, Duisburg, Germany) according to the standard ICC Method 115D (ICC, 1992), using a 50 g mixing bowl.

A rounded portion of dough (15 g) was collected after 6 min mixing in the farinograph hand placed in a round plastic container (diameter 40 mm). Dough stickiness was evaluated using a TA-HDplus Texture Analyzer (Stable Micro Systems, Surrey, UK), equipped with a 10 N load cell. After five min, each sample was submitted to compression with a plate probe (diameter: 35 mm) at a crosshead speed of 1 mm/s. The sample was compressed up to 30% deformation, and maintained at this deformation for 5 s, before releasing the force pulling the probe off the sample at a speed of 1 mm/s. Data were collected and elaborated using the Texture Exponent TEE32 V 3.0.4.0 Software (Stable Micro System, UK). Stickiness was evaluated as the negative area of the force-time curve measured during force removal. The time of plate detachment from the sample was also considered. Four replicates were performed for each sample.

2.5. Leavening properties

Leavening properties were measured as reported by Rollini, Casiraghi, Pagani, and Manzoni (2007) with some modifications. Just after bread dough preparation (see section below), six aliquots (10 g each) were collected, molded in a spherical shape, put into six Petri dishes, and leavened in a climatic chamber up to 4 h at 30 °C and 80% of relative humidity. At the beginning of the test, and then every 30 min, the images of the Petri dishes were scanned full scale in 256 grey level at 300 dpi with a flatbed scanner (Epson Perfection 3170 Photo, Saiko-Epson Corporation, Japan). Images were processed using Image Pro-Plus (4.5.1.29, Media Cybernetics Inc, MD, USA). The dough area (mm^2) increase was measured and the relative increase was considered (A_t/A_{t0}).

2.6. Bread preparation

Bread loaves were prepared according to the official method AACC 10–10.03 (AACC International, 2000) with some modifications. Flour (50.0 g) was mixed with sucrose (2 g; Eridania Italia S.p.A, Italy), salt (1.0 g; Italkali, Italy), shortening (animal origin; 1.5 g), yeast (1.75 g; Lesaffre Italia S.p.A, Italy), and ascorbic acid (0.4 mg; Sigma Aldrich SRL, Italy). Water was added based on the