Food Chemistry 195 (2016) 64–70

Contents lists available at ScienceDirect

Food Chemistry

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

The use of potato fibre to improve bread physico-chemical properties during storage

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ARTICLE INFO

Article history:
Received 28 November 2014
Received in revised form 2 March 2015
Accepted 5 March 2015
Available online 28 March 2015

Keywords:
Potato fibre
Bread staling
^{1}H NMR molecular mobility
Physico-chemical properties

ABSTRACT

Bread staling reduction is a very important issue for the food industry. A fibre with high water holding capacity, extracted from potato peel, was studied for its ability to reduce bread staling even if employed at low level (0.4 g fibre/100 g flour). Physico-chemical properties (water activity, moisture content, frozen water content, amylopectin retrogradation) and ^{1}H Nuclear Magnetic Resonance molecular mobility were characterised in potato fibre added bread over 7 days of storage. Potato fibre addition in bread slightly affected water activity and moisture content, while increased frozen water content and resulted in a softer bread crumb, more importantly when the optimal amount of water was used in the formulation. Potato fibre also reduced ^{1}H NMR molecular mobility changes in bread crumb during storage. Potato fibre addition in bread contributed to reduce bread staling.

1. Introduction

Bread staling is a process occurring during storage of the product, that results in crumb hardening, crust softening and loss of the characteristic fresh flavour of the product (Gray & Bemiller, 2003). Different phenomena contribute to bread staling: starch recrystallization is one of the factors contributing to crumb hardening, as well as gluten dehydration and its consequent loss of plasticity, and modified gluten–starch interactions. Water plays a fundamental role in bread staling and, hence, the study of water status and dynamics is very important to better understand the bread staling phenomenon. Water migrates from crumb to crust at a macroscopic level and redistributes at a molecular level, becoming partially incorporated in starch crystals, looses phase separating capability (decreased "DSC freezable water" content) and is redistributed among bread domains (Baik & Chinachoti, 2001; Curti, Carini, Tribuzio, & Vittadini, 2014; Schiraldi & Fessas, 2001; Slade & Levine, 1991; Vittadini & Vodovotz, 2003).

Addition of large amounts of fibre into bread to produce high fibre products has been object of much research in an effort to improve customers' fibre intake but it is often detrimental to bread quality (Chen, Rubenthaler, Leung, & Baranowski, 1988; Katina, Salmenkallio-Marttila, Partanen, Forssell, & Autio, 2006). Large amounts of fibre are known to negatively modify dough and bread properties, production process, and staling-related phenomena (e.g. gluten dehydration, amorphous starch recrystallisation, water molecular redistribution among bread components; Collar, Santos, & Rosell, 2007; Fadda, Sanguinetti, Del Caro, Collar, & Piga, 2014; Gray & Bemiller, 2003). However, with the selection of the proper type of fibre and proper technological fibre treatment, fibre addition can improve bread properties and retard staling (Laurikainen, Harkonen, Autio, & Poutanen, 1998; Sangnark & Noomhorm, 2003, 2004; Wang, Rosell, & Barber, 2002).

Potato peel, a by-product from the potato industry, has been reported to be a very rich (higher than wheat bran) and good source of fibre with high water-holding capacity (Camire & Flint, 1991; Camire, Violette, Dougherty, & McLaughlin, 1997).

Few works considered the effect of potato peel as a source of fibre in bread (Toma, Orr, D'Appolonia, Dintzis, & Tabekhia, 1979) and cakes (Sharoba, Farrag, & El-Salam, 2013), reporting higher farinograph absorption, reduced gas retention and volume, as well as increased hardness in the products. In all these reports potato peel was added in large amounts (5–20%) to bread formulations in an effort to increase bread fibre content. Based on its characteristics and properties, potato fibre may also have an effect on water status and dynamics, possibly retarding and modulating bread staling.

The aim of the present work is to investigate a potential technological use of potato fibre in improving bread physico-chemical properties and reduce bread staling. Potato fibre was,

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http://dx.doi.org/10.1016/j.foodchem.2015.03.092
0308-8146/

therefore, added in small amount into a bread formulation, and its effect on physico-chemical properties and water status of the product was studied during storage.

2. Materials and methods

2.1. Bread formulation, production and storage

Three breads were produced. The control sample was named STD and it was produced with optimal water amount (500 Brabender Units). The formulations [wheat flour (Molino Seragni, Cremona, Italy); sugar (Coprob S.C.A., Pavia, Italy); salt, (Italkali s.p.a., Palermo, Italy); yeast (AB Mauri Italy s.p.a., Padova, Italy); sunflower seeds oil (Oleificio Zucchi, Cremona, Italy)] are reported in Table 1.

Potato fibre (HI-FIBRE 115, HI-FOOD s.p.a., Collecchio, Italy), extracted from the potato peel and very rich in soluble components, was added to the formulation at 0.4% on a flour basis (g fibre/100 g flour) to produce two samples, P-W and P-STD. The water absorption used for P-W was increased of 4%, according to preliminary trials aiming at identify the conditions (fibre and water level) to obtain an optimised final product in terms of volume, colour, and texture. P-STD was produced with the same amount of water used for STD to clearly highlight the effect of fibre. Potato fibre composition (as indicated by the producer) was the following: ~6.0% (g/100 g fibre) moisture, protein <1.0%, fat <1.0%, carbohydrates <1.0%, dietary fibre ~92.0% (soluble fibre ~73.0%; insoluble fibre ~19.0%), ashes ~2.0%.

Breads were produced with a home bread-maker (Backmeister 68511, UNOLD, Germany) using a "basic" program (pre-heating 17 min; first kneading 5 min; second kneading 13 min; first fermentation 45 min; smoothing 1 min; second fermentation 18 min; smoothing 1 min; third fermentation 45 min; baking 55 min), cooled to room temperature, placed in polyethylene bags sprinkled with about 3 ml ethanol, and stored at room temperature. Samples (three loaves for each sample for each storage time) were analysed fresh (day 0) and after 1, 3, 5 and 7 days of storage.

2.2. Volume and texture

Volume was measured on three bread loaves for each sample following the American Association Cereal Chemistry 10-05 method (Guidelines for Measurement of Volume by Rapeseed Displacement).

Bread crumb hardness was measured with a TA.TX2 Texture Analyzer (Stable Micro Systems, Goldalming, UK). At least eight cubic portions ($2 \times 2 \times 2$ cm^3) of crumb were extracted from the central slices of the bread loaf and compressed (force = 0. 05 N) to 40% deformation using a cylindrical probe (P/35 Dia Cylinder Aluminium). Crumb texture was described in terms of hardness (maximum height of the first compression peak) and cohesiveness (ratio of the areas of the second to the first compression peak).

Table 1
Bread formulations.

Ingredient (%)	STD	P-W	P-STD
Wheat flour	100.0	100.0	100.0
Potato fibre	0	0.4	0.4
Sugar	4.0	4.0	4.0
Salt	2.0	2.0	2.0
Yeast	3.0	3.0	3.0
Water	59	64	59
Sunflower seed oil	3.0	3.0	3.0

2.3. Water activity and moisture content

Water activity of crumb (from loaf centre) and crust was measured with a dew point instrument (Aqualab 4TE, Decagon Devices, WA, USA). At least five measurements were taken for each sample. Moisture content (MC) of crumb (from loaf centre) and crust were determined in triplicate for each bread loaf by weight loss at 105 °C (NSV 9035, ISCO, Milan, Italy) to constant weight.

2.4. Frozen water content and retrograded amylopectin

Crumb thermal properties were measured with a Differential Scanning Calorimeter (DSC Q100 TA Instruments, New Castle, DE, USA), calibrated with indium and mercury. Bread crumb (4 g from loaf centre) was properly compressed to obtain a flat and compact crumb sample to maximise heat transfer within the DSC cell during the experiment. Samples (5–10 mg) were taken and placed in stainless steel pans (Perkin Elmer, USA) that were then hermetically sealed, quench cooled to −80 °C and heated at 5 °C/min to 130 °C. DSC thermograms were analysed (Universal Analysis Software 3.9A, TA Instruments, New Castle, DE). "Frozen" water (at the given experimental conditions; FW) was calculated from the endothermic peak around 0 °C (ice melting) using the following equation:

$$\mathrm{FW} = \text{Enthalpy Ice Fusion} \times \left(\frac{1}{\text{latent heat ice fusion}}\right) \times \left(\frac{1}{\mathrm{MC}}\right) \times 100$$

where FW is frozen water at the given experimental conditions (g frozen water/100 g water), Enthalpy Ice Fusion (J/g product), Latent heat of ice fusion is 334 J/g ice and MC is moisture content (g water/g product).

Retrograded amylopectin (J/g sample) was obtained by the integration of the endothermic peak in the 50–80 °C temperature range.

2.5. Molecular mobility (^{1}H NMR)

A low resolution (20 MHz) ^{1}H NMR spectrometer (the MiniSpec, Bruker Biospin, Milano, Italy) operating at 25.0 ± 0.1 °C was used to measure the Free Induction Decay (FID) and the transverse (T_2) relaxation times of the samples. Crumb samples (10 mm high) were prepared in 10 mm NMR tube, sealed with Parafilm® to prevent moisture loss during the NMR experiment.

FIDs were acquired using a single 90° pulse, followed by a dwell time of 7 μs, 32 scans and a recycle delay of 3 s and a 10 ms acquisition window. ^{1}H FIDs were analysed in the time range 7–100 μs where the homogeneity of magnetic field was assured. Fitting of FID was carried out with a two components model (exponential and gaussian, Le Grand, Cambert, & Mariette, 2007; Sigmaplot, v6, Systat Software Inc. USA):

$$I(t) = y0 + A * \exp[-(t/T_A)] + B * \exp[-(t/T_B)^2]$$

where $y0$ is the FID decay offset, A and B are the are intensities of each relaxation component, T_A and T_B are the apparent relaxation times.

T_2 relaxation times were measured with a CPMG pulse sequence with a recycle delay of 3 s ($\geqslant 5$ ^{1}H T_1), an interpulse spacing of 0.04 ms and 4000 data points. Quasi-continuous distributions of relaxation times were obtained from the experimental T_2 curves using a UPENWin software (Alma Mater Studiorum, Bologna, Italy). Default values for all UPEN parameters were used with the exception of one (LoXtrap) that was set to 1 to avoid extrapolation of relaxation times shorter than the first experimental point.