Journal of Cereal Science 59 (2014) 145–154

Contents lists available at ScienceDirect

Journal of Cereal Science

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

Pseudocereals and teff in complex breadmaking matrices: Impact on lipid dynamics

Concha Collar*, Alessandro Angioloni

Cereal Group, Food Science Department, Instituto de Agroquímica y Tecnología de Alimentos (CSIC), Avda. Catedrático Agustín Escardino, 7, 46980 Paterna, Spain

A R T I C L E I N F O

Article history:
Received 16 October 2013
Received in revised form
22 November 2013
Accepted 9 December 2013

Keywords:
Pseudocereals
Bread
Nutritional quality
Functional properties
Lipid dynamics

A B S T R A C T

The use of pseudocereals and ancient grains for breadmaking applications is receiving particular attention since they involve nutrient dense grains with proven health-promoting attributes. Dilution up to 20% of the basic rye/wheat flour blend by accumulative addition of amaranth, buckwheat, quinoa and teff flours (5% single flour) did positively impact either some dough visco-metric and visco-elastic features, or some techno-functional and nutritional characteristics of mixed bread matrices, and induced concomitant dynamics in lipid binding over mixing and baking steps. A preferential lipid binding to the gluten/non gluten proteins and to the outside part of the starch granules takes place during mixing, in such a way that the higher the accumulation of bound lipids during mixing, the higher the bioaccessible polyphenol content in blended breads. During baking, lipids bind to the gluten/non gluten proteins at the expenses of both a free lipid displacement and a lipid migration from the inside part of the starch granules to the protein active sites. It was observed that the higher the decrease of free lipid content during baking, the higher the pasting temperature and the lower the total setback on cooling and the dynamic moduli, but the higher the specific volume in blended breads.

1. Introduction

Revisiting under-utilized plant species such as pseudocereals and ancient grains for breadmaking applications arises from the finding and promotion of nutritionally and health-related relevant attributes. Their innovation is rather related to the ways in which old and new uses are being readdressed, since pseudocereals and ancient grains have been used by local populations in traditional ways for many centuries (Dini et al., 2012). Pseudo-cereal flours with some nutritional and functional features preferable to cereal flours (Fessas et al., 2008), can be excellent sources of proteins, vitamins, minerals, fibre, and other important nutrients (Coda et al., 2010), and show antioxidant, antinflammatory, and anticarcinogenic activities (Lin et al., 2008). Pseudocereal proteins are highly soluble and characterized by foaming and emulsifying properties (Schoenlechner et al., 2008). The amino acid profile of the proteins of amaranth is comparable to that of egg, and the nutritional quality of the proteins of quinoa is comparable to that of caseins (Schoenlechner et al., 2008). Compared to cereals, quinoa has a higher concentration of fat with elevated levels of unsaturated fatty acids and phospholipids which, due to the presence of vitamin E, remain stable during storage (Ng et al., 2007). In addition, quinoa shows a balanced amino acid spectrum with high methionine and lysine contents (Peiretti et al., 2013). Teff (*Eragrostis tef*) is a nutritious cereal grain indigenous to Ethiopia, rich in carbohydrate and fibre, that contains more iron, calcium and zinc than other cereal grains, including wheat, barley and sorghum (Abebe et al., 2007), and constitutes a promising basic ingredient for achieving healthy cereal products (Alaunyte et al., 2012).

The nutritional properties and baking characteristics of amaranth, quinoa and buckwheat have been assessed in gluten-free matrices (Alvarez-Jubete et al., 2010), achieving breads with superior nutritional features and acceptable sensory scores. In wheat flour matrices, some studies demonstrated the feasibility of partial/low replacement of wheat flour with pseudocereals for processing baked goods (Tosi et al., 2002; Schoenlechner et al., 2008; Angioloni and Collar, 2011a, b). The use of a blend of buckwheat, amaranth, chickpea and quinoa flours subjected to sourdough fermentation by selected γ-aminobutyric acid (GABA)-producing strains allowed the manufacture of a bread enriched with GABA and should be considered as a promising possibility for enhancing nutritional, functional, sensory, and technological properties of bread. The addition of quinoa and/or buckwheat seeds (at levels of 30 and 40%) previously subjected to an hydrothermal

* Corresponding author. Tel.: +34 963 90 00 22; fax: +34 963 63 63 01.
E-mail address: ccollar@iata.csic.es (C. Collar).

0733-5210/$ – see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jcs.2013.12.008

process, resulted in a valuable effect on the nutritive value of the breads (Demin et al., 2013). Teff flour, despite being gluten-free, has been reported to produce high-quality leavened flatbread aging much slower than if made from other cereals, in particular sorghum (*Sorghum bicolor* (L.) Moench) (Taylor and Emmambux, 2008). Replacement of up to 30% of wheat flour by teff flour in the presence of a mixture of amylolytic and non amylolytic enzymes can lead to acceptable breads (Alaunyte et al., 2012).

Pseudocereals and teff flours exhibit higher qualitative and quantitative lipid profiles than wheat flours do (Hager et al., 2012). Lipids have a significant effect on the quality and texture of baked goods because of their ability to associate with proteins, due to their amphipathic nature (hydrophilic and hydrophobic groups present), and with starch, forming inclusion complexes (Goesaert et al., 2005). In breadmaking applications, protein and starch lipid binding in wheat flour and bread systems have been reported to correlate with loaf volume, crumb structure, softness and/or texture of bread (Collar et al., 2001). At dough level and in presence of surfactants, free and bound lipids preferentially bind to gluten (monoglycerides) and to the outside part of the starch granules (cationic surfactants). Hydrocolloids preferentially bind to the gluten and to the outside part of the starch granules depending on their polarity (Collar et al., 1998). In wheat bread, a preferential binding of the added anionic surfactant to the starch with a concomitant displacement of endogenous polar lipids from starch to gluten was observed (Collar et al., 2001). In single and blended oat, rye, buckwheat and wheat flour matrices, lipids bound to proteins during dough mixing are translocated and bound to starch during baking. Starch lipid showed the most significant correlations with parameters related to dough and bread performance during breadmaking, especially over the mixing step (Angioloni and Collar, 2011a,b).

This research is aimed at characterising the lipid fractions at flour, dough and bread stages of single and blended amaranth, buckwheat, quinoa and teff added to a wheat/rye matrix, prior to analyse the significance of starch- and protein-lipid binding on the functional and nutritional properties of associated grain matrices during mixing and baking.

2. Experimental

2.1. Materials

Commercial flours from refined (70% extraction rate) common Wheat *Triticum aestivum* (W), and whole Rye *Secale cereale* (R), Amaranth *Amaranthus caudatus* – (A), Buckwheat *Fagopyrum esculentum* (B), Quinoa *Chenopodium quinoa* (Q) and Teff *Eragrostis tef* (T) were purchased from the Spanish market. Ireks *Vollsauer* sour dough was from Ireks (Spain); commercial compressed yeast was from Lesaffre (France); Novamyl 10000 a maltogenic intermediate thermostable alpha amylase was purchased from Novozymes (Denmark).

2.2. Methods

2.2.1. Chemical, functional and nutritional composition of flours

Moisture, protein, ash and fat contents of commercial flours W, R, T, A, B and Q were determined following the ICC methods 110/1, 105/2, 104/1, and 136, respectively (ICC, 1976–1996). Total, soluble and insoluble dietary fibre contents were determined according to the AOAC method 991.43 (AOAC, 1991). Two replicates were made for each flour analysis. Digestible carbohydrates were calculated by difference (FAO, 2003). Solvent-Retention Capacity (SRC) was determined according to AACC method 56-11 (AACC, 2005). The Water-Holding Capacity (WHC) was determined as described by Traynham et al. (2007). Fat adsorption capacity (FAC) was determined according to Ahn et al. (2005). Foam capacity (FC) and Foam stability (FS) were determined as described by Alu'datt et al. (2012).

2.2.2. Breadmaking of blended flours

Doughs and breads were prepared for a) control (W-R, 50:50, wt:wt), b) singly added A, B, Q and T at 5% W-R flour basis, respectively, c) binary added QA, QB, QT, AB, AT, and BT at 10% (5% + 5%) W-R flour basis, respectively, d) ternary added QAB, QAT, ABT, and QBT at 15% (5% + 5%+5%) W-R flour basis, respectively, and quaternary added QABT at 20% (5% + 5%+5% + 5%) W-R flour basis, respectively. 16 different blended flours were obtained. Blended flour, water (88% -WR-, 89% -Q-, 90% -A-, 91% -B- and 92% -T-, flour basis), commercial compressed yeast (4% flour basis), salt (1.5% flour basis), sugar (2% flour basis), commercial sour dough (10% flour basis), skimmed milk powder (5%, flour basis), Novamyl (7.5 mg, flour basis) and calcium propionate (0.5%) were mixed in a 10 kg mixer at 60 revolutions min^{-1} for 10 min up to optimum dough development. Fermented doughs were obtained after bulk fermentation (10 min), dividing (300 g), rounding, molding, and proofing up to a maximum volume increment (30 min), and were baked at 200 °C for 30 min to make control, and pseudocereal- and teff- enriched breads. Breads were sliced (2 cm) and stored in polypropylene bags for 1, 3, 6, 8 and 10 days at 22 °C until analysis.

2.2.3. Dough functionality

Dough functional behaviour was assessed by either fundamental or empirical dough physical tests. Dough viscoelasticity was determined by dynamic oscillation tests on an RS1 controlled stress rheometer equipped with a Phoenix II circulating bath (Haake, Karlsruhe, Germany) using a 60-mm serrated plate–plate geometry with a 1-mm gap between plates (Angioloni and Collar, 2012a). Strain sweep tests were run to identify the linear viscoelastic region. Oscillatory measurements of storage modulus (G′) and loss modulus (G″) were performed at 25° C within a frequency range from 0.1 to 10 Hz. All measurements were made in triplicate. Viscometric properties – dough pasting profiles (gelatinization, pasting, and setback properties) – were obtained with a Rapid Visco Analyser (RVA-4, Newport Scientific, Warriewood, Australia) using ICC standard method 162 (Collar, 2003). RVA parameters were calculated from the pasting curve using Thermocline v. 2.2 software.

2.2.4. Bread measurements

2.2.4.1. Physico-chemical and sensory determinations. Specific volume was assessed by seed displacement, and aspect ratio was calculated as width/height ratio of central slides. Colour determinations were carried out on bread crumb and crust using a Minolta colorimeter (Minolta CR- 400, Konica Minolta Sensing, Inc., Osaka, Japan), and results were expressed in accordance with the Hunter Lab colour space. Parameters determined were *L* (L = 0 [black] and L = 100 [white]), a (−a = greenness and +a = redness), and b (−b = blueness and +b = yellowness). Sensory analysis of fresh breads was carried out by a consumer acceptability test. Overall acceptability was tested by a group of 30 consumers using a 9 point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely). Bread primary and secondary mechanical characteristics (TPA in a double compression cycle) of fresh and stored breads were recorded in a TA-XTplus texture analyser (Stable Micro Systems) using a 10 mm diameter probe, a 5 kg load cell, 50% penetration depth and a 30 s gap between compressions on slices of 20 mm width. For textural measurements, three slices of two breads were used for each sample at different storage periods (0–10 days). The obtained firming curves were modelled using the Avrami equation (Armero and Collar, 1998).