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Processing & rheological properties of wheat flour dough and bread containing high levels of soluble dietary fibres blends

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ABSTRACT

Wheat flour doughs were processed with soluble dietary fibres (DF) added up to 40% (w/w flour). DF were made of a ternary mixture of maltodextrins (MT, 3/5), pectins (PE, 1/5) and inulin (IN, 1/5). The addition of DF decreased the specific mechanical energy developed by the mixer, mainly because of water addition. It increased the ratio of storage moduli and the elongational viscosity of the dough, but decreased the strain hardening index. Energy input and rheological changes at mixing largely explained the decreases of porosity characteristic time and stability time during fermentation. It was possible to add up to 30% DF with a moderate increase of bread density, and 20%, with little change of crumb cellular structure. Hence, the changes of bread crumb texture were not mainly due to bread density, but rather likely to the changes of properties of the intrinsic material. Results obtained by addition of single fibre source, especially inulin, deviated from the main trends observed for texture and rheological properties. These results provide a good basis to design breads with increased dietary fibre content.

1. Introduction

For a healthy diet, a large daily dose of dietary fibre (≥25 g/day) is recommended, that is far higher than the consumption observed in most countries (Anderson et al., 2009). Dietary fibres may be classified according to their solubility, which have significant impact on their physiological functionality (Arcila, Weier, & Rose, 2015). Soluble fibres cover a wide range of ingredients, from oligosaccharides to hydrocolloids, and are known to present prebiotic effects (Angioloni & Collar, 2008; Rosell, Santos, & Collar, 2009). These prebiotic effects may lie in the capacity of these fibres (fructoligosaccharides, arabinoxylanes, or resistant starches for instance) to generate active metabolites such as butyrate and propionate, which are short chain fatty acids produced by degradation of the fibres by the colon microbiota (de Vadder et al., 2014). Many studies on physiological impact of dietary fibres have focused on the effect of a single source of fibres which impacts bacteria consortia (Delzenne, Neyrinck, & Cani, 2013), but seldom address the effect of DF blends, which could favor the bacterial diversity via the production of a wider variety of metabolites signals, butyrate and propionate in particular.

Cereals products provide opportunities to develop foods that deliver health benefits for a large population (Ishwarya & Prabhasankar, 2014). Therefore, bread is a good target for fibre enrichment, which requires substitution of wheat flour in the dough recipe. Besides, the physiological effects of fibre addition in bread have already been studied (see for instance Christensen et al., 2013). However, the accurate interpretation of the results of such studies is not straightforward since the addition of fibres, soluble or insoluble, modifies its structure and texture, especially density, which, in turn, will affect the kinetics of digestion and the availability of nutrients (Saulnier, Micard, & Della Valle, 2014). In addition, these modifications will also affect the rheological properties of dough and its processing until final bread texture, which may be detrimental to its sensory properties (Poutanen, Sozer, & Della Valle, 2014). Therefore, when processing functional foods, like breads enriched in fibres, it is essential to strive to maintain the same texture properties, a point which is often discarded. The use of enzymatic and fermentation or physical (extrusion) processes that can tune the solubility of fibres before incorporation to bread recipes (Arcila et al., 2015; Gomez, Jimenez, Ruiz, & Oliete, 2011; Salmenkallio-Marttila, Katina, & Autio, 2001) may be useful in this purpose. However, there is a need to ascertain the effects of soluble fibres at different stages of breadmaking (mixing, fermenting, baking), with emphasis on dough rheological properties and bread specific volume and texture.

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Indeed, addition of soluble fibres may lead to negative effects on dough properties (Morris & Morris, 2012) regarding water absorption, dough development, elasticity and stickiness, which all affect bread sensory properties, especially by increasing density. The main mechanisms of action of soluble fibres (SF) on dough rheological properties have been described by Courtin and Delcour (2002) in the case of water extractable arabinoxylans, with emphasis on dough behavior during processing. Due to variable hydration properties, SF addition first requires an adjustment of water addition during mixing (Hager et al., 2011; Morris & Morris, 2012). Regarding dough rheological properties, the measurements of linear viscoelastic properties (small amplitude oscillations, SAO) have shown that the increase of storage modulus with SF addition, mainly pentosans, could be attributed to a reinforcement of gluten network (Santos, Monteiro, & Lopes da Silva, 2005; Wang, Hamer, van Vliet, & Oudgenoeg, 2002), although opposite result, network weakening, has been found when adding pentosan (Migliori & Gabriele, 2010) or pectin (Angioloni & Collar, 2008). Results from large strain rheological measurements, out of the linear viscoelastic domain, can be linked to process behavior. However, such works about the effect of SF addition are quite seldom, either because dough containing SF are difficult to handle, due to increased stickiness and modified or because such measurements are less popular than SAO measurements. Using uniaxial compression test, Cavella, Romano, Giancone, and Masi (2008) showed that dough elongational viscosity and strain hardening index decreased when adding up to 9% inulin, which suggest worse gas retention performance during dough fermentation and, consequently, lower final bread volume.

Specific volume (or density) is the main target property of bread and it has been shown to increase with addition of low SF amounts. Generally, crumb texture changes (firmness, hardness), observed when adding arabinoxylans, inulin, extruded bran, β-glucans, can be explained, at first, by density changes (Courtin & Delcour, 2002; Cavella et al., 2008; Peressini & Sensidoni, 2009; Gomez et al., 2011; Hager et al., 2011; Morris & Morris, 2012; Rubel, Pérez, Manrique, & Genovese, 2015). Finally, the effects of SF incorporation on dough and bread properties depend on the type of fibre, the addition level and the step of breadmaking process studied. Actually, the effect of SF addition, at levels larger than 10% of flour substitution, has never been studied at different steps of the breadmaking process, likely because of negative effects on dough properties. Moreover, as opposite effects are sometimes encountered, according to the source of fibres, it may be possible to balance those, i.e. reducing the negative ones, by using a blend of different sources. As mentioned earlier, this could enhance the prebiotic effect by favoring the bacterial diversity.

In this context, our aim was to determine to which extent a blend of soluble fibres could be added to wheat flour dough for breadmaking. In this purpose, inulin, pectin and maltodextrins were added at various levels to wheat flour, either single, or binary and ternary blends and the resulting changes of dough properties and bread texture were assessed with rheological and imaging methods.

2. Materials and methods

2.1. Raw materials and dough compositions

French wheat flour (WF, 13%, g protein/g dry flour, dry basis, d.b., 0.55% ash) was supplied by Moulin Girardeau (France). 3 different soluble dietary fibres (DF) were tested: (1) high methoxyl pectin (PE, Unipectine QC 100, Cargill, Germany), (2) short chain inulin (IN, Instant, DP ≤ 10, Cargill, France) and (3) maltodextrins from tapioca starch, named resistant starch (MT, C ActiStar 11,700, Cargill, France, about 50% crystalline with melting DSC peak at 110 °C), which all dissolved in water, at bare eye. Fresh yeast (Springer Lesaffre, France), dried refined fine salt (Salinor, France) and tap water were used in the bread making experiments.

13 different formulations of wheat flour and DF were studied (Table 1). The control formulation consisted of 2000 g wheat flour, 1240 g tap water, 40 g fresh yeast, 36 g salt and 0.04 g ascorbic acid. Six formulations were obtained by adding a mixture of DF, composed of 60% MT, 20% IN, 20% PE (% g fibre/g total fibre content), at different levels (on flour basis, f.b.): 5%, 10%, 20%, 25%, 30% and 40% (dough # 5, 6, 10, 11, 12, 13, respectively). This DF mixture composition is selected because it aims to optimize microbiota diversity and fermentation processes in the gut for the consumer's health benefit (Endo, Niioka, Kobayashi, Tanaka, & Watanabe, 2013). Then 3 formulations resulted from the individual addition of 4% PE, 4% IN, 12% MT, on flour weight basis (#2, 3, 7), or combined in pairs (#4, 8, 9); both addition levels correspond to the same amount of the fibre ingredient as in formulation containing 20% DF (#10).

Tap water addition was adjusted by an expert baker for each formulation at the end of pre-mixing stage in view of dough behavior and mechanical power measurements, in agreement with the French bread making procedure (AFNOR standard V03-716). This procedure includes a protocol for the breadmaking process and provides an evaluation grid of the dough quality according to six criteria: smoothing aspect, stickiness, consistency, extensibility and slackening. The capacity of the expert baker to reason efficiently over a variety of production contexts about the relations between the flour constituents, the ingredients and the mixing process conditions with the dough quality, defined according to these criteria, has been validated by Kansou, Chiron, Della Valle, Ndiaye, and Roussel (2014).

2.2. Breadmaking procedure

Mixing was carried out in a spiral mixer (Diosna SP12, GmbH, Germany). Mixing protocol consisted of 3 different steps. First, wheat

Table 1
Composition of dough formulations (/2000 g wheat flour basis, f.b.), in maltodextrins from tapioca starch (MT), Inulin (IN) and Pectin (PE), DF the amount of added fibres, (% flour sub.)[a] fibres substituting flour, and MC the water content on total wet basis.

Formulation & symbol	MT (g)	IN (g)	PE (g)	DF (% f. b.)	Fibre (% flour sub.)[a]	Water (% f. b.)	MC (%tot. w.b.)
1 △	0	0	0	0	0.0	64.0	46.5
2 ○	0	0	80	4	3.8	88.0	52.1
3 ●	0	80	0	4	3.8	62.0	44.8
4 □	0	80	80	8	7.4	78.0	48.5
5 ▲	60	20	20	5	4.8	69.3	46.8
6 ▲	120	40	40	10	9.1	78.0	48
7 ●	240	0	0	12	10.7	73.3	46.2
8 ■	240	0	80	16	13.8	87.6	49.0
9 ■	240	80	0	16	13.8	71.7	44.7
10 ▲	240	80	80	20	16.7	93.0	49.4
11 ▲	300	100	100	25	20.0	99.0	49.6
12 ▲	360	120	120	30	23.1	106.0	50.0
13 ▲	480	160	160	40	28.6	122.5	51.3

[a] This value is the mass of DF over the mass of DF + flour.