Dietary fibre enzymatic treatment: a way to improve the rheological properties of high-fibre enriched dough

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Dietary fibre enzymatic treatment: a way to improve the rheological properties of high-fibre enriched dough

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The demand for functional products is increasing, driven largely by the market interest in foods suitable for improving the health and well-being of consumers (Charalampopoulos *et al.*, 2002). In this regard, diets rich in dietary fibre (DF) are more and more recommended, since it is widely accepted that Non-Starch Polysaccharides (NSP) are associated with the prevention of cardiovascular diseases, the regulation of intestinal function, the promotion of gut health, and the protection against colon cancer (Kumar *et al*., 2012). Bakery products, particularly bread, may be a convenient tool for increasing DF content in habitual western diet, since they are consumed daily in high amounts.

However, the long chains in NSP molecules interfere with the development of a regular and strong gluten network, resulting in a worsening of the rheological properties and handling of bread dough, giving loaf with low volume, hard crumb, bitter flavour, and dark colour (Ktenioudaki & Gallagher, 2012). The negative effect of fibre on bread texture and consumer acceptability is greatly dependant on the type and components, level of substitution, and particle size of the fibre (Ktenioudaki & Gallagher, 2012). Many approaches have been employed to improve the quality of fibre-enriched bread, mainly based on the use of bioprocessing such as fermentation (Salmenkallio-Marttila *et al*., 2001; Katina *et al*., 2006) and/or on the addition of enzymes or additives directly in the bread formulation (Laurikainen *et al.*, 1998; Haros *et al.*, 2001; Katina *et al.*, 2006; Shah *et al.*, 2006). Consequently, in all these studies the enzymatic action is simultaneous to the bread-making process. None of the enzymatic treatments already proposed has been carried out as a pre-treatment of the fibre. Only Napolitano *et al.* (2006) highlighted that the conversion of the highly polymerised insoluble dietary fibre of durum wheat into soluble feruloyl oligosaccharides can be achieved by using hydrolytic enzymes. However, no information is available on the effect of fibre enzymatic treatment on the rheological properties of wheat dough when total fibre content is higher than 6%. The aim of the present work was to investigate the modifications induced by enzymatic treatment of fibre on the rheological properties of fibre-enriched bread dough.

Oat bran (cv. Raisio, Finland) containing 15% beta-glucans (BG15; total starch = 26 g/100 g; protein = 19 g/100 g; lipids = 10 g/100 g;) was used in this study. The enzymatic hydrolysis of the samples was performed with a commercial food grade cellulolytic and glycosidic enzyme mixture (Cytolase M102, Genencor International, New York, USA, with a cellulase activity of 2400 viscosimetric units, measured as detailed by Caldini *et al.* (1994)), obtaining BG15+E sample. An aliquot of 50 µl of the enzyme solution was added to one gram of sample suspended in 4 ml of deionised water. The suspension was placed in agitation for 6 hours at 25 °C, then freeze dried, according to Caldini *et al.* (1994). The amount of total (DF), soluble (SDF) and insoluble dietary fibre (IDF) was determined according to the gravimetric enzymatic method proposed by Prosky *et al.* (1988). The soluble residue in the supernatant was measured after centrifugation of the mixture at 4000 *x g*, for 15 min at 25°C, and overnight drying at 105°C. Sugar content was determined according to Zygmunt *et al.* (1982). Microscopy images were obtained by means of an Olympus BX50 microscope, using Lugol (I_2KI) as staining.

Untreated and treated fibre samples were added to a common wheat flour of good baking properties (protein = 13.8 g/100 g; fiber content 2.95g/100g; alveographic W = 358 $*10^{-4}$ J; alveographic P/L = 0.55) in order to prepare a bread dough enriched with 20 g BG15/80 g flour or 20 g BG15+E/80 g flour. Dough mixing properties were evaluated with the farinographic test (Brabender OHG, Duisburg, Germany). Dough development and CO_2 produced from the yeast activity during the leavening phase were measured by means of a Rheofermentometer F3 (Chopin, Tripette & Renaud, Villeneuve La Garenne, France).

The data were processed by Statgraphic Plus for Windows v. 5.1. (StatPoint Inc., Warrenton, VA, USA). A one-way analysis of variance (Anova) was performed using the Least Significant Differences (LSD) test to compare the sample means; differences were considered significant at $P < 0.05$.

The enzymatic treatment of fibre was associated with a significant decrease in the total fibre content (Table 1). In particular, the SDF/IDF ratio greatly changed; this trend could be related to the formation of disaccharides and/or other soluble oligosaccharides having size and molecular weight too low to be classified as SDF by using the Prosky method (Prosky *et al*., 1988). This finding was confirmed by a significant increase of the soluble residue and by the higher sugar content measured after enzymatic treatment (Table 1). The relevant breakdown of the macrostructure of NSP into smaller species was also made evident by microscopy (Fig. 1). Before the enzymatic treatment, BG15 sample appears characterized by fibre particles between 500 and 650 μm in size (Fig. 1a). The enzymatic action caused a disintegration of the fibre particles, broken down to fractions in the 20-100 μm range (Fig. 1b).

The effects of the enrichment in fibre on mixing properties, as evaluated by the farinographic test, are reported in Fig. 2. As expected, the water absorption and the development time of the flour increased, whereas the stability decreased. The high water affinity of the NSP and the weakening effect of fibre on dough have been already described (Sudha *et al*., 2007). On the contrary, adding high level of untreated fibre resulted in an increase of both water absorption of the dough and development time, accounting for a difficult workability. Adding enzymatically treated fibre promoted a decrease of the amount of water absorption and a more relevant impact on the macromolecule hydration and, consequently, on the development time (see insert in Fig. 2).

The dough development during leavening and the amount of gas produced and retained by the dough system of the dough enriched with fibre was investigated by the rheofermentographic test. The addition of untreated fibre compromised a good dough development (Fig. 3). This phenomenon had been attributed to impaired protein hydration in presence of NSP (Sudha et al., 2007). The addition of pre-treated fibre allowed a fast and great dough development, likely due to the sugar formation promoted by the enzymatic treatment. With regard to the ability of the dough to produce CO2, the incorporation of BG15+E to flour resulted in a product with high gas production and retention, very similar to that obtained for the common wheat flour (see insert in Fig. 3).

These results suggest that the enzymatic treatment allows to add high level of soluble fibre (>5%) to the flour without worsening the dough properties during both mixing and leavening. The enzymatic pre-treatment proposed in this study may be easily applied by milling companies both for the enhancement of wheat milling by-products and for increasing their range of products. From the point of view of the final user, in a production reality as the Italian one, characterized by numerous small bread-making companies where very often experience and tradition matter more than a scientific approach, the use of pre-treated flours/ingredients permits to minimize some of the problems associated with the direct use of enzymes in bread-making.

Further studies are currently being carried out to investigate the effect of treated fibre on bread characteristics.

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137 Table 1. Fibre and sugars content (g/100g db) of untreated and enzymatically treated high fibre samples.

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140 Figure 1. Microscope images of untreated (a) and enzymatically treated (b) high fibre samples.

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142 Figure 2. Mixing properties of untreated and treated fibres.

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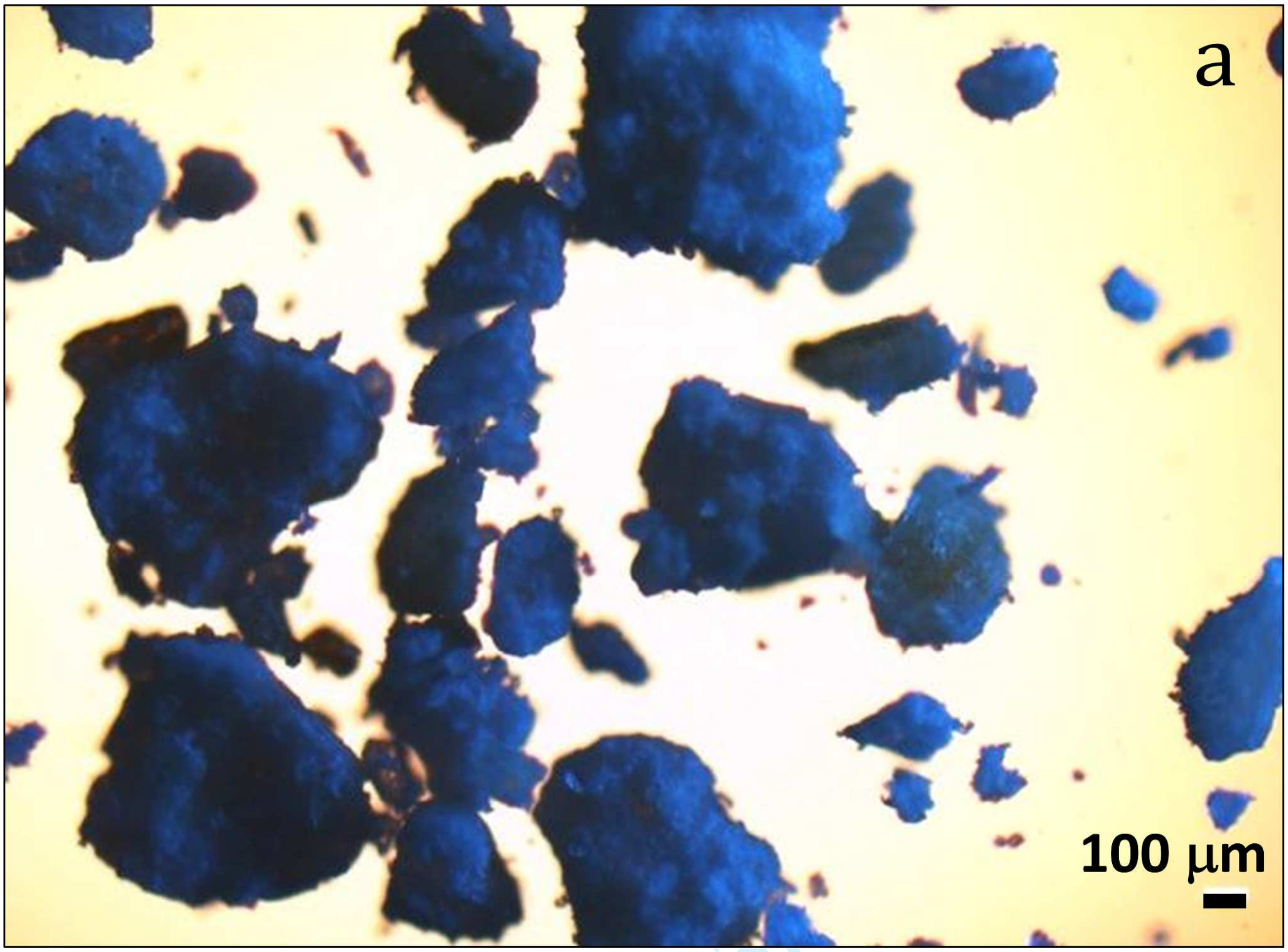
Table 1. Fibre and sugars content of untreated and enzymatically treated high fibre samples.

BG15 = oat bran (15% beta-glucans); BG15+E = enzymatically treated oat bran (15% beta-glucans).

Parameters	BG15	BG15 + E
	(g/100g db)	
Total Fibre	31.10 ± 0.93b	24.10 ± 0.72a
Soluble Fibre	15.36 ± 0.46a	20.23 ± 0.61b
Insoluble Fibre	15.69 ± 0.47b	3.89 ± 0.12a
Soluble/Insoluble Fibre ratio	0.98	5.2
Soluble residue	11.8 ± 0.35b	23.5 ± 0.71a
Sugars	3.16a	5.19b
Glucose	0.03 ± 0.001a	3.22 ± 0.04b
Fructose	0.07 ± 0.002a	1.10 ± 0.005b
Sucrose	2.34 ± 0.01b	0.18 ± 0.02a
Maltose	0.40 ± 0.05b	0.27 ± 0.04a

Different letters in the same line are significantly different (Least Significant Differences; $p<0.05$).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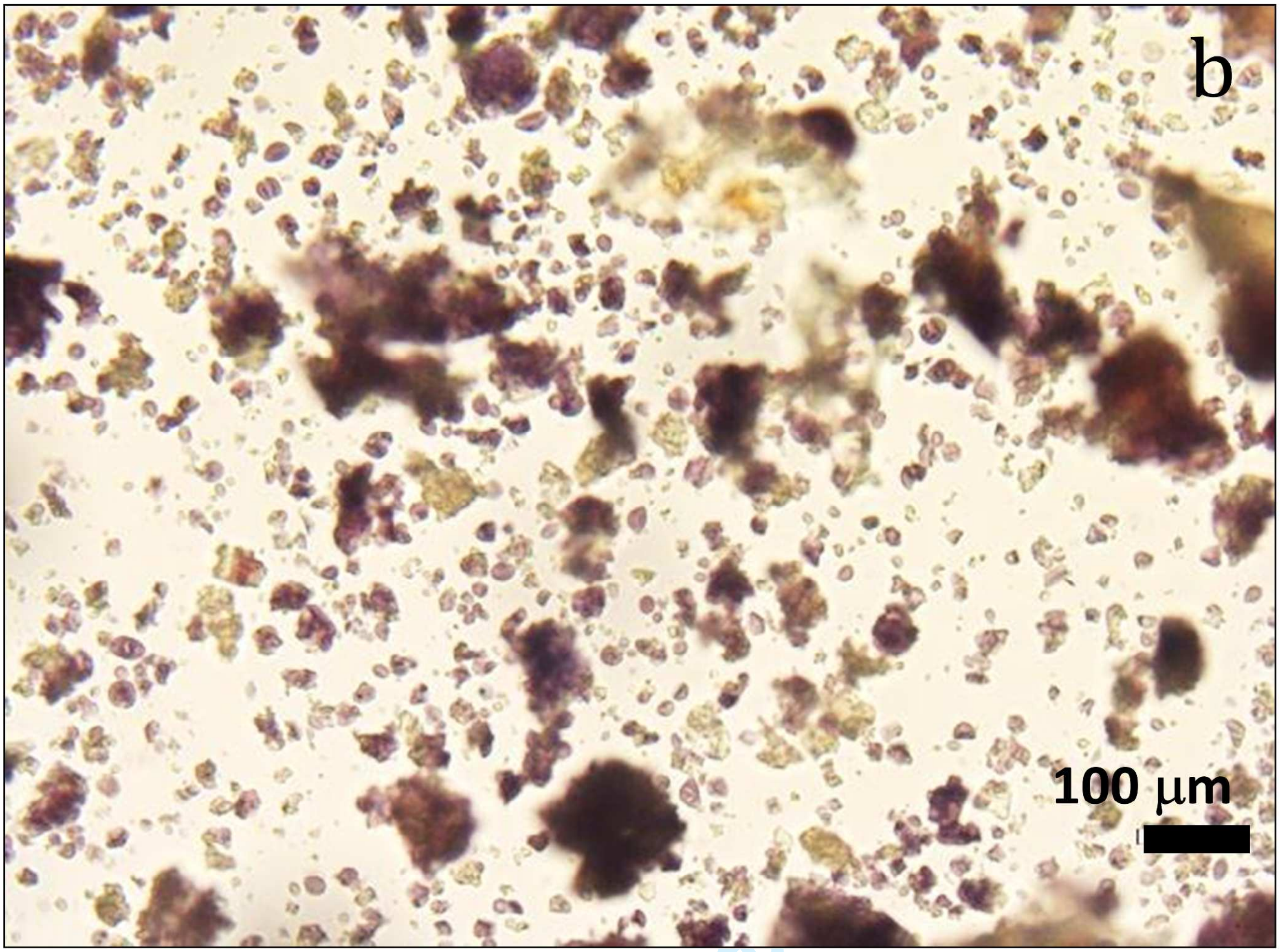

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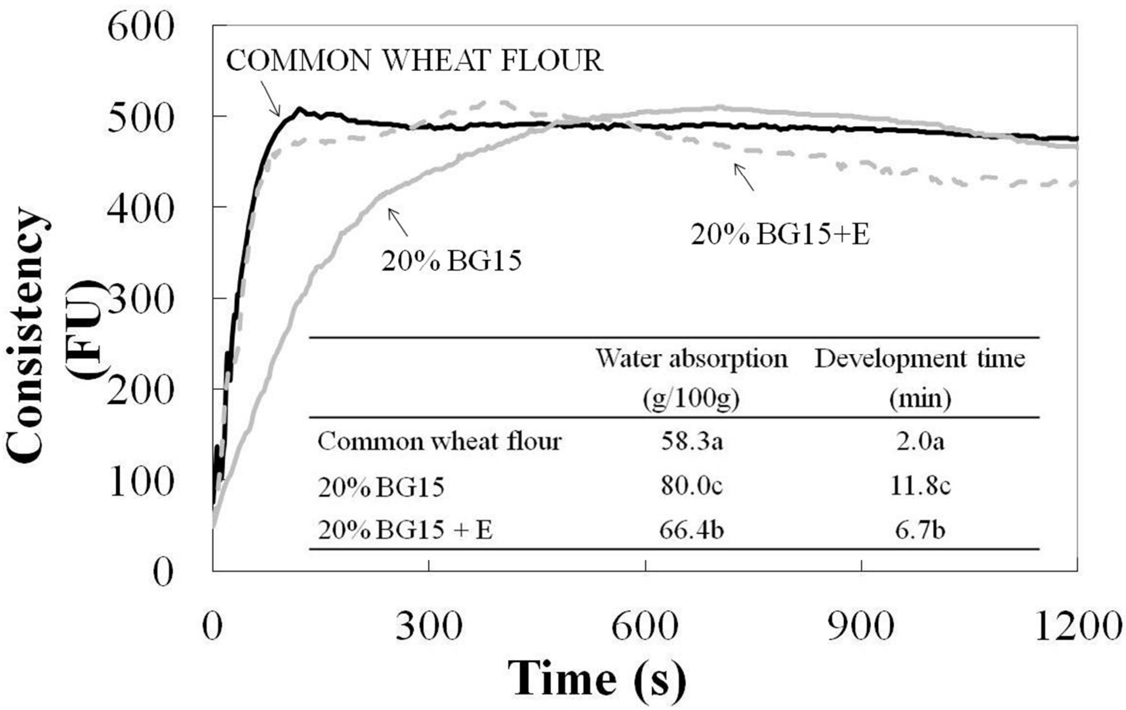

	Water absorption (g/100g)	Development time (min)
Common wheat flour	58.3a	2.0a
20% BG15	80.0c	11.8c
20% BG15 + E	66.4b	6.7b

Figure 2. Mixing properties of untreated and treated fibres.

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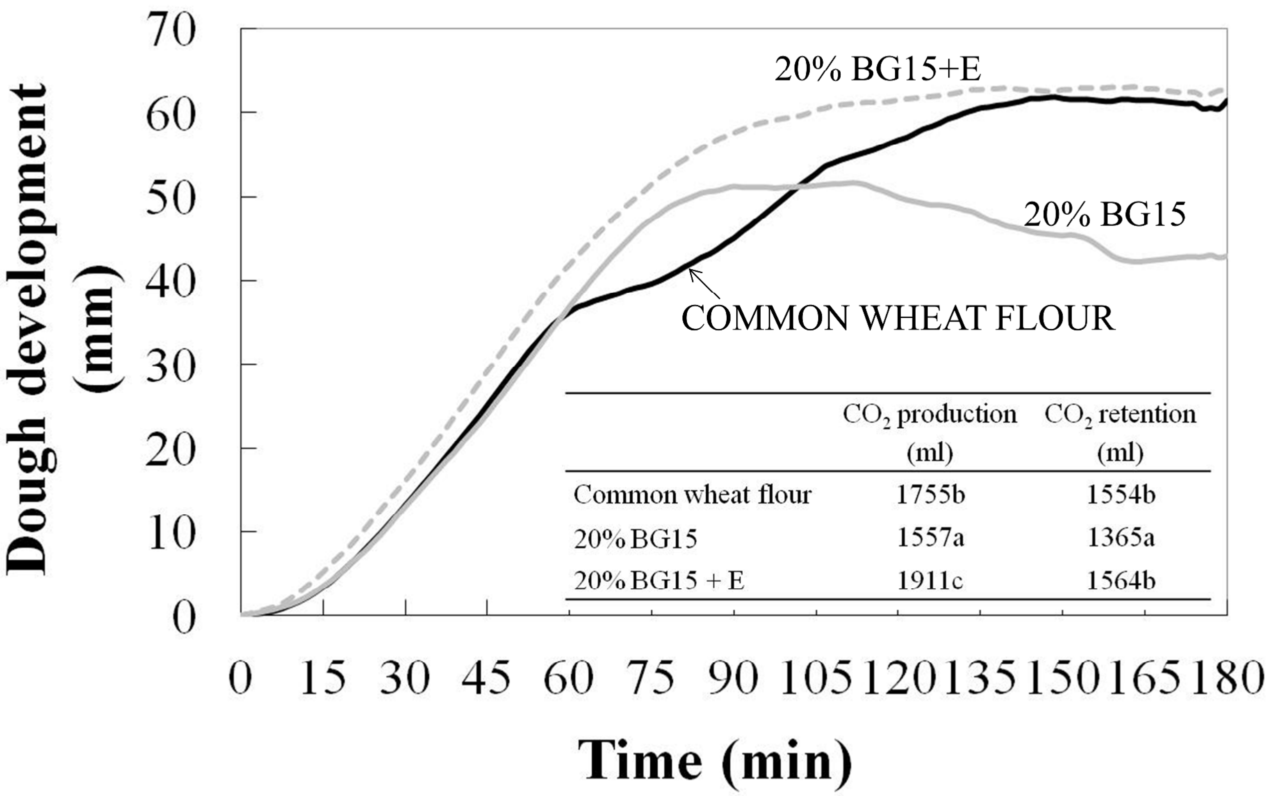

Figure 3. Leavening properties of fibre-enriched wheat dough. Different letters in the same parameter are significantly different (Least Significant Differences; $p<0.05$).

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