Effect of High-Pressure Processing on the Features of Wheat Milling By-products

DOI:10.1094/CCHEM-07-13-0133-CESI

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ABSTRACT

The ability of high hydrostatic pressure processing to promoting changes in both the structural properties of fiber and of the interaction of fiber with water were addressed. Both coarse and fine bran from milling of common wheat were considered. Treatment-induced morphological changes were most pronounced in fine bran, whereas treatment of coarse bran resulted in the largest change of water holding capacity. The significance of the process-induced changes is discussed as for their practical relevance in the production of fiber-enriched foods.

High hydrostatic pressure (HHP) processing uses high hydrostatic pressure (usually between 100 and 1000 MPa) to improve food shelf-life and, in some cases, to modify food properties (Hayashi 1991). HHP modifies the structure of biopolymers (protein, starch, and DNA), thus producing foods with novel texture and providing satisfying effects (Estrada-Giron et al 2005). HHP processing has been shown to significantly affect the amorphous and ordered starch structure and, thus, to cause starch gelatinisation as a function of applied pressure, treatment time and temperature, concentration and type of starch (Pei-Ling et al, 2010). Recent studies demonstrated that the HHP treatment of gluten-free cereal raw materials may improve baking performance of gluten-free cereals, mostly as a consequence of changes in their protein fractions that may occur concomitantly with modifications in other biopolymers in the system (Huttner et al 2009; Huttner et al 2010; Vallons et al 2011).

The application of HHP processing and its effect on wheat milling by-products has not been much studied until now. The objective of this study was to investigate the effects of HHP treatment on microstructure and hydration properties of by-products from wheat milling. This could promote changes in overall structural properties of fiber resulting in improved quality and easier handling of fiber-enriched dough, and promote further intervention on fiber structure (e.g., enzymatic treatments aimed at altering the soluble/insoluble ratio).

MATERIALS AND METHOD

Coarse and fine bran from common wheat were supplied by Molino Quaglia S.p.A. (Vighizzolo D’Este, Padova, Italy). The particle size distribution of both samples are reported in Table 1.

HHP processing was performed on both coarse and fine bran. For each HHP treatment, 8 g of sample were added to 80 ml of deionised water and sealed in a plastic bag after 15 minutes of resting. Treatment was carried out at SSICA in a QFP 35L-600, (Avure Technologies, Franklin, TN, USA), at

36 °C and 600 MPa for 5 or 15 minutes. The treated mixture was freeze-dried within 4 h from treatment and kept at 0−4 °C until further analysis.

Water-holding capacity (WHC), swelling capacity (SC), and water binding capacity (WBC) were determined, in triplicate, as reported by Lebesi and Tzia (2012) with few modifications. WHC (g/g) was expressed as the residue hydrated weight and the original sample weight ratio. SC (ml/g) is defined as the ratio of the volume occupied when the sample is immersed in excess of water after equilibration to the actual weight. WBC (g/g) was defined as the quantity of water that remains bound to the hydrated fiber following the application of an external force (centrifugation).

Microscopy images were obtained by means of an Olympus BX50 microscope, using Lugol (I_2KI) as staining. Coarse and fine bran, before and after HHP processing, were incorporated at 20% replacement level to a wheat flour of good bread-making properties (protein = 14.5 g/100 g; alveographic W = 430 $*10^{-4}$ J; alveographic P/L = 0.80).

The effect of treatment on gluten aggregation properties of bran-enriched flour was measured using the GlutoPeak (Brabender GmbH and Co KG, Duisburg, Germany), that allows to measure rheological parameters of highly hydrated flours under conditions of high shear stress. An aliquot of 9 g of blend was dispersed in 10 ml of distilled water. Sample temperature was maintained at 35 °C by circulating water through the jacketed sample cup. The paddle was set to rotate at 3000 rpm and each test ran for 5 min. The time required to achieve maximum torque development (Peak Maximum Time, PMT; s) and the area under the peak (equivalent to energy, and expressed in arbitrary units) were considered. Measurements were performed at least in triplicate.

Data were processed by Statgraphic Plus for Windows v. 5.1. (StatPoint Inc., Warrenton, VA, USA). 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 $P < 0.05$.

RESULTS AND DISCUSSION

Hydration properties

The hydration properties of samples before and after HHP treatment are presented in Figure 1. Water Holding Capacity (WHC) is the ability of the hydrated fiber matrix to retain water, in the form of linked water, hydrodynamic water, and physically trapped water, the latter contributing most to this property (Alfredo et al 2009). A fiber WHC is highly indicative of its physiological role in intestinal function and in blood sugar level control (Wolever 1990). Coarse bran retained more water than fine bran (Figure 1). HHP processing significantly ($p<0.05$) affected WHC, almost regardless of treatment time ($p>0.05$). Since the structural characteristics and chemical composition of fiber play important roles in water uptake and consequently in swelling (Figuerola et al 2005), the increase in WHC after HHP treatment could be explained by a modified organization of some fiber component.

Swelling Capacity (SC) indicates to what extent the fiber matrix swells as water is absorbed (Femenia et al 2009). The SC of coarse bran did not change after HHP processing (Figure 1). In the case of fine bran, HHP treatment increased the swelling ability by 25%.

Water Binding Capacity (WBC) is related to the sample ability to strongly bind water. Untreated coarse bran showed a slightly higher WBC than fine bran (Figure 1), confirming that water binding to fiber decreases as particle size decreases (Auffret et al 1994). Particle size and shape affect the centrifuge separation performance of the material, as coarse wheat bran is less firmly packed than smaller particle bran after centrifugation (Zhang and Moore 1997). The HHP treatment promoted a greater increase in WBC in the case of fine bran (24%) than in coarse bran (10%), confirming the greater effect of HHP processing on the hydration properties of fine bran. Again, no significant ($p>0.05$) differences were measured according to the time of treatment. For this reason, further investigation was carried out on samples treated just for 5 minutes.

Microstructural features

Microscope images of coarse and fine bran before and after HHP treatment are shown in Figure 2. Coarse bran has many particles greater than 1000 μm; the largest one also reached 1500 ÷ 2000 μm (Figure 2a). Fine bran ranged from 500 μm to 1000 μm (Figure 2b). HHP-treated samples have a size smaller than the corresponding untreated samples (Figure 2c, d). In both cases. particles of 100÷200 μm with a less compact structure appeared after HHP processing, suggesting that the treatment promoted a weakening of the structure and its fragmentation, thus accounting for the change in hydration properties (Figure 1).

Gluten aggregation behaviour

The GlutoPeak Test (GPT) is a new approach for testing gluten quality, that uses shear force to uniformly mix flour and water and measures the torque associated with high-speed mixing. The GPT profiles of flour and bran-enriched flours are shown in Figure 3. As the gluten aggregation develops, the shear force increases as does the energy required for mixing.

Peak Maximum Time (PMT) relates to the time required for gluten to aggregate and to exhibit maximum spindle torque. The addition of any type of bran significantly ($p<0.05$) decreased PMT indicating a weakening of the gluten network, as observed in presence of cellulosic fiber (Goldstein et al 2010).

The area under the peak is an indicator of the amount of work required for mixing and gluten formation. Bran significantly decreased this parameter ($p<0.05$), again suggesting a worsening of gluten aggregation properties. HHP processing gave a significant ($p<0.05$) increase in PMT (only for coarse bran) and a significant ($p<0.05$) increase in energy for both coarse and fine bran. These effects could be related to changes in both bran hydration properties (Figure 1) and particle size (Figure 2).

Indeed, if tightly bound water is only available, it will take more time and energy to get the water-dependent structural changes involved in gluten development (Huschka et al 2011).

CONCLUSIONS

This work indicates that HHP processing alters the physical and structural characteristics of milling by-products, and – as a consequence – their ability to interact with water. HHP-induced morphological modifications were greater in the case of fine bran and resulted in large changes in the bran hydration properties. The hydration properties of bran are relevant in many cereal-based systems where water availability at various process stages (e.g, during mixing in bread or pasta making) affects the handling of mixtures, and the physical and sensory properties of the resulting product. Furthermore, the highly solvated bran that forms as a consequence of HHP treatment could be a convenient substrate for bioconversions aimed either at modifying the structural/nutritional features of the product (for example, by altering the ratio between soluble and insoluble bioactive poly- and oligosaccharides), or for improving the recovery of other bioactive components, such as polyphenols.

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Table 1

Coarse and fine bran particle size distribution (expressed in g/100g).

	Coarse bran	**Fine bran**
> 800 µm	32	1
500 ÷ 800 µm	35.1	35.1
350 ÷ 500 µm	27.5	40.2
180 ÷ 350 µm	5.4	20.2
50 ÷ 180 µm	0	3.4
< 50 µm	0	0.1

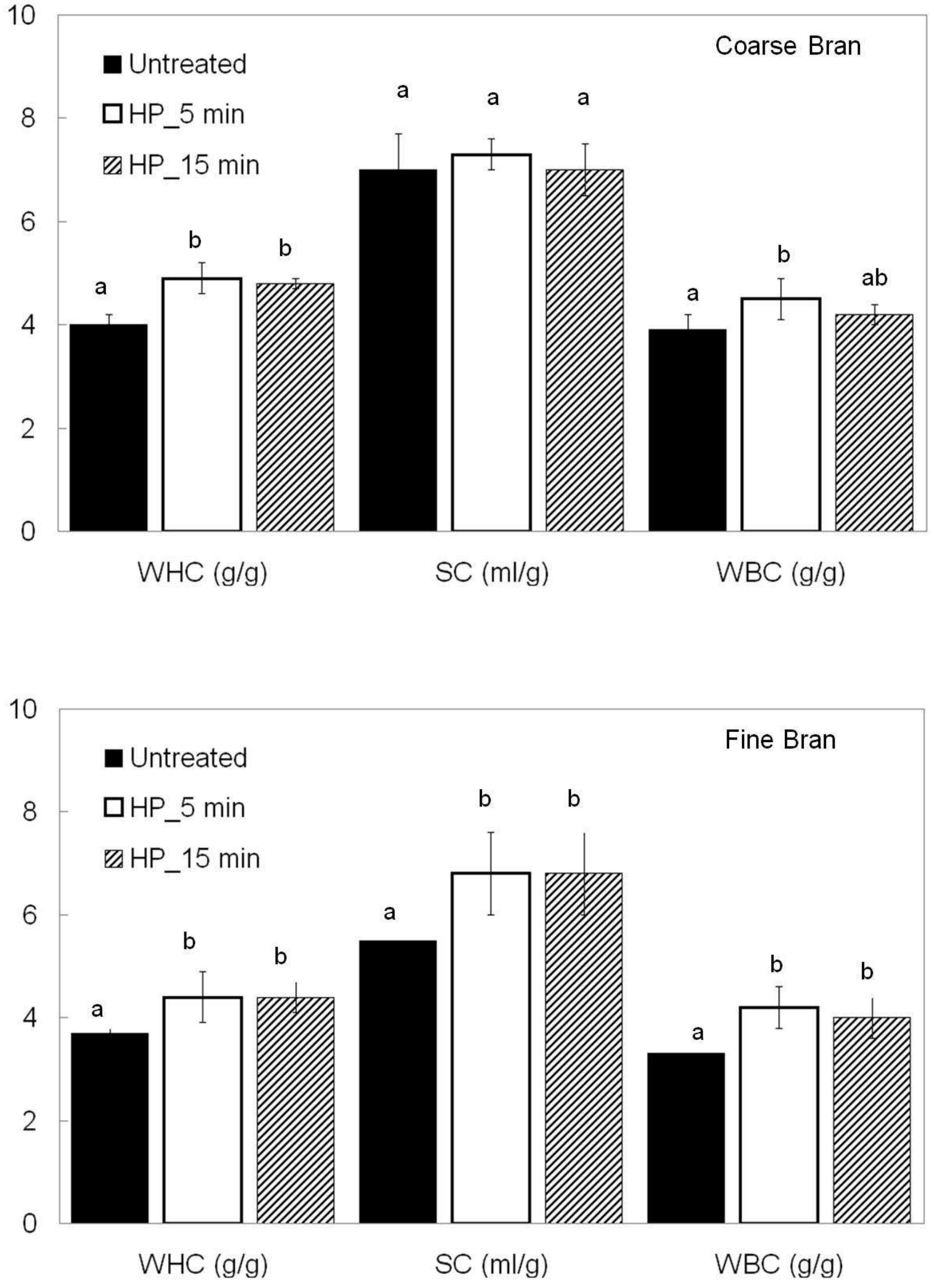
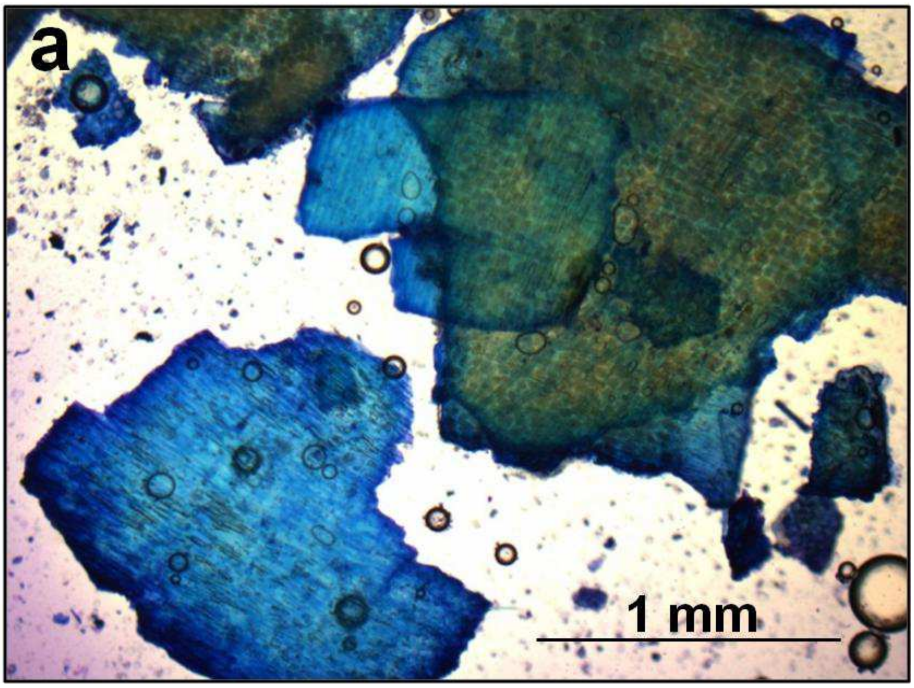


Fig. 1. Hydration properties of coarse and fine bran, before and after HHP processing.

HP_5 min = sample after HHP processing for 5 minutes; HP_15 min = sample after HP processing for 15 minutes; WHC = water holding capacity; SC = swelling capacity; WBC = water binding capacity. Different letters for each parameter are significantly different ($p<0.05$).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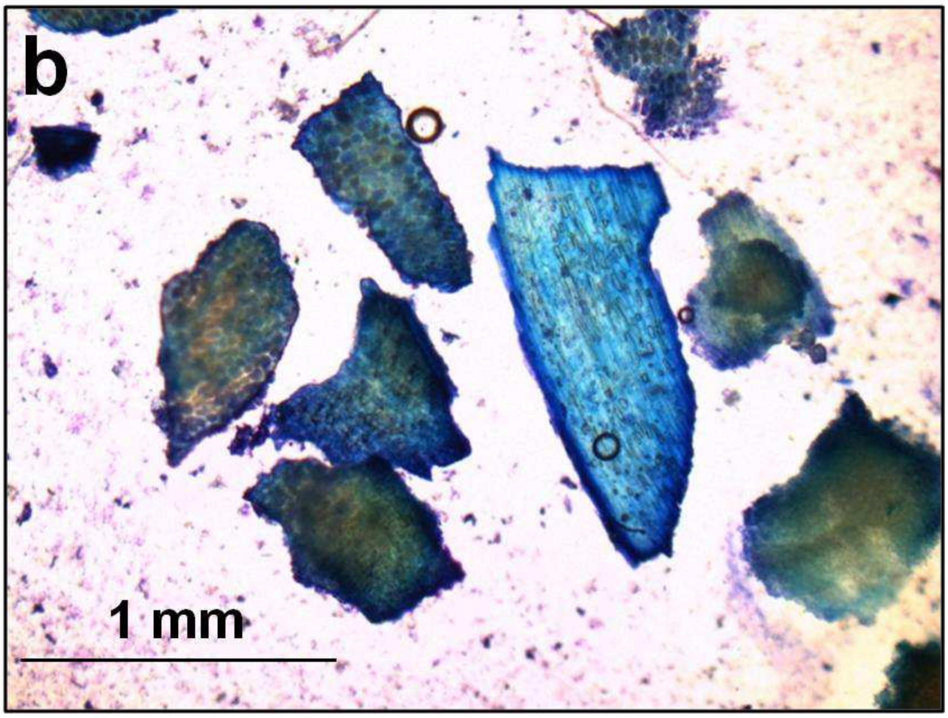
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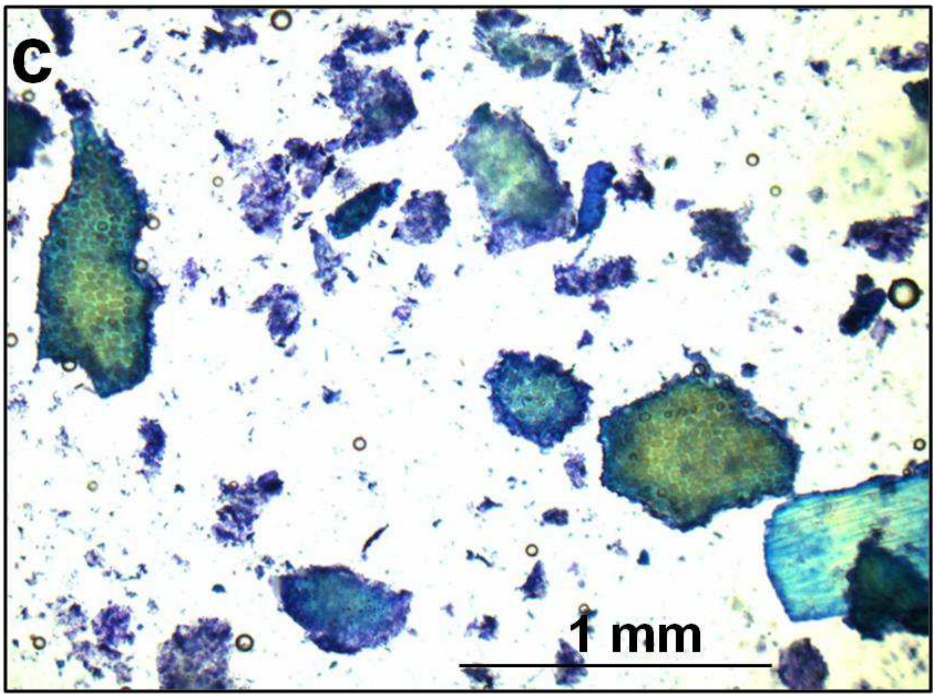

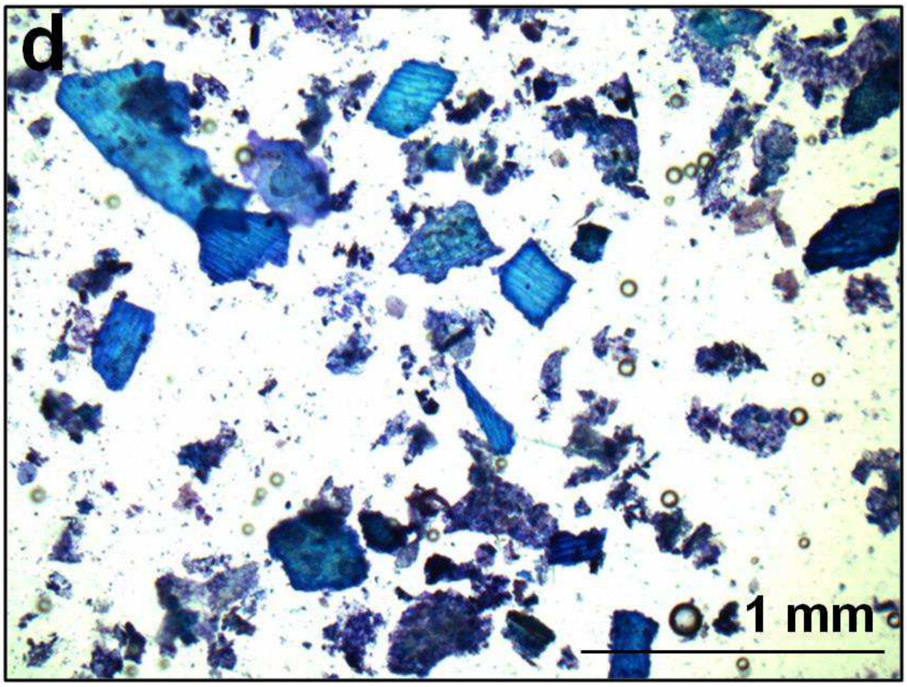

Fig. 2. Microscope images of coarse (a) and fine (b) bran and effects of HHP processing on coarse (c) and fine (d) bran.

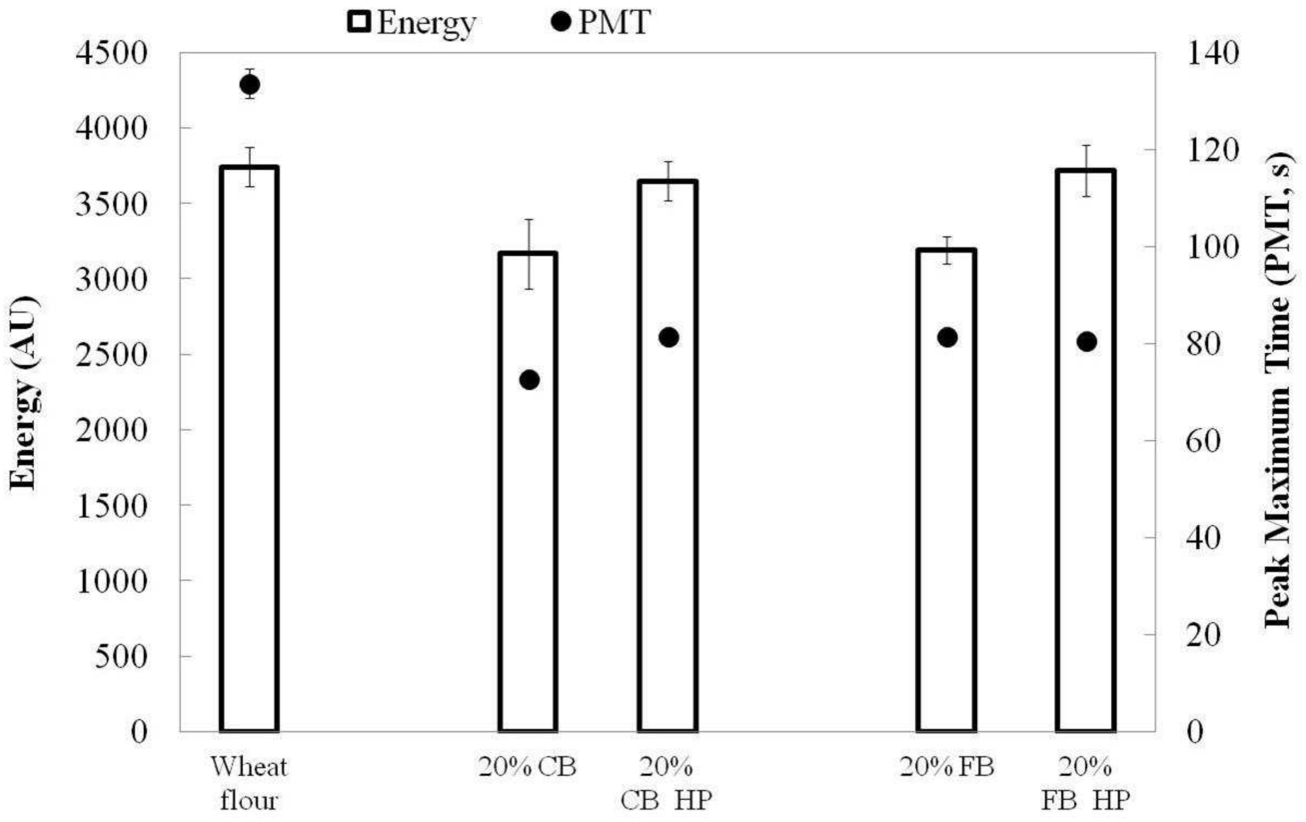

Fig. 3. Gluten aggregation properties of bran-enriched flour. PMT = Peak Maximum Time, is indicated by dots. Column height refers to energy, measured by considering the area underneath the torque peak, and given in arbitrary units. CB = coarse bran; HPCB_5 = coarse bran after HHP processing for 5 minutes; FB = fine bran; HPFB_5 = fine bran after HHP processing for 5 minutes.