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Effects of high hydrostatic pressure on quality changes of blends with low-protein wheat and oat flour and derivative foods

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ABSTRACT

This study aimed to investigate the effect of high hydrostatic pressure (HHP) on the physicochemical characteristics of blended low-protein wheat (LW) and oat flour. Additionally, quality changes in noodles made from blends treated with HHP were investigated. Crude protein and fiber contents of LW were not affected by HHP; however, those of blends were significantly higher than those of LW ($p < 0.05$). Water-holding capacity (WHC) of blends increased with HHP treatment. The peak viscosity of LW did not differ significantly because of HHP, and the peak and final viscosities of blends increased upon oat flour addition. The hardness, gumminess, chewiness of noodles made using LW improved with the addition of oat flour combined with HHP. The results indicated that the use of blends containing LW and oat flour as well as HHP treatment improved the quality and properties of noodles made using LW.

1. Introduction

Wheat (*Triticum aestivum* L.) is a major food source along with rice and is mainly consumed worldwide in various preparations, such as bread, noodles, and other bakery products. The suitability of wheat flour for wheat-based food production can be gauged on the basis of protein content of the flour, which has been traditionally considered as a predictor of wheat-based food quality (Zhou et al., 2013). Among the various types of wheat-based foods, fried, boiled, dry, and fresh noodles are popular and frequently consumed foods in Korea (Lee, Kim, & Kang, 2017; Kang et al., 2010).

Changes in genetic and climatic factors, seeding date, N-fertilizer application, and environmental factors affect wheat cultivars during growth and can alter the components of wheat flour, including protein content, thereby greatly affecting the final quality of processed wheat-based food products (Bhat, Wani, Hamdani, Gani, & Masoodi, 2016; Naeem, Paulon, Irmak, & MacRitchie, 2012; Gao, Lukow, & Grant, 2012; Wieser, 2007). Low-protein wheat flour, which was unintentionally produced because of various environmental factors or cultivation methods, is not desirable because it does not positively affect the quality of final products such as noodles and bread. Protein content of wheat flour for optimal noodle quality is required to be approximately 10% (Nagao et al., 1977). Hence, low-protein wheat is distributed at low cost and has limited applications in Korea (Lee, 2016).

Oats, a commonly consumed whole-grain, contain many phytochemicals with antioxidant activity, such as tocols, flavonoids, phytic acid, and phenolic acids (Peterson, 2001; Chu et al., 2013). Recently, public interest in the unitization of oat components, such as bran and β-glucans, as dietary fiber in healthy food formulation has increased (Zhu, 2017). In addition, protein content of oats ranges from 9 to 15%, with a high lysine content (Zhu, 2017). Inglett, Chen, Liu, and Lee (2014) reported that oat and chia blends could be valuable for developing new functional foods because of their nutritive value, e.g., β-glucan, omega-3 linolenic acid, and omega-6 linoleic acid components and physical properties such as improved water-holding capacity, texture, and useful viscoelastic qualities. Moreover, the particle size of samples is an important factor influencing the dough mixing properties and product quality such as appearance (Johansson, Andersson, Alminger, Landberg, & Langton, 2018; Niu, Hou, Lee, & Chen, 2014).

High hydrostatic pressure (HHP) processing, a non-thermal food preservation technology, has become increasingly well-known in the food industry as a means of spoilage prevention and inactivation of pathogenic microorganisms (Park et al., 2017). High-pressure treatment has advantages over thermal treatment, such as its ability to produce foods with novel textures such as lower digestibility, retrogradation, and gelatinization enthalpy from cereal starch and to preserve food quality (Stolt, Oinones, & Autio, 2001; Guo et al., 2015; Hu, Zhang, Jin, Xu, & Chen, 2017). In the present study, we hypothesized that HHP and blending with oat flour would positively affect the quality of low-protein wheat flour and its associated products. Hence, this

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study aimed to investigate the effect of HHP on physicochemical characteristics of blended low-protein wheat and oat flour.

2. Materials and methods

2.1. Sample preparation

Korean low-protein winter wheat (LW) was obtained from the Department of Rice and Winter Cereal Crop, National Institute of Crop Science (Wanju, Jeonbuk, Korea). Wheat cultivars were dried and then milled using a Buhler milling machine (MLU-202; Buhler, Uzwil, Switzerland). Oat grain was purchased from a local store in Jeongeup, South Korea. Whole oat grain was ground with a milling machine (HMF-1710, Hanil Co., Asan, Korea), and then separated into 500-μm (BO50) and 850-μm (BO85) particle size groups using a sieve. Samples of low-protein wheat were blended with 500-μm and 850-μm oat flour at 20% and 40% concentrations, respectively. The particle size of the oat flour was based on that of the commercially available powder. The concentration and particle size of the samples obtained after blending were adjusted after preliminary experiments to prepare blends of LW and oat flour for noodle quality.

2.2. High hydrostatic pressure (HHP) treatment

HHP treatment was performed with a cold isostatic press machine (ISA-CIP-S30-200, Ilshin Autoclave Co., Ltd., Daejeon, Korea) and chamber size was 200 x 600 cm. Blended samples were placed in nylon bags (20 × 30 cm^2, 80-μm-thick) and vacuum-packed using a vacuum packaging machine (SR-900H, Intrise Co., Ltd., Ansan, Korea). Packed samples were treated with HHP at 150 and 300 MPa for 30 min at 25 °C using a water press. The samples were placed in plastic bags and stored at 4 °C until further use.

2.3. Approximate composition, crude fiber, β-glucan, and water-holding capacity (WHC)

The approximate compositions of the samples, including moisture, ash, and crude protein contents, were measured in accordance with the official methods of the American Association of Cereal Chemists (AOAC, 1986). Total crude fiber content was determined using a dietary fiber analyzer (Dosi-fiber, J.P Selecta s.a, Barcelona, Spain). β-Glucan content was analyzed in accordance with the Approved Method 995.16 (AOAC, 1986). Total starch content was measured using Approved Method 996.11 (AOAC, 1986). WHC of the samples was determined in accordance with the methods of Medcalf and Gilles (1965) and Kim and Shin (2007). The samples (1 g) were mixed with 40 mL of distilled water, agitated for 1 h and centrifuged at 2000 × *g* for 30 min. WHC was expressed as g water retained per g samples.

2.4. Pasting profiles and scanning electron microscopy (SEM)

The pasting properties of the sample were confirmed using a Rapid Visco Analyzer (RVA 4500; Perten Instruments, Hägersten, Sweden) in accordance with the manufacturer's flour method. Sample was based on 14% moisture contents. The peak viscosity, final viscosity, breakdown viscosity, setback viscosity, peak time and pasting temperature were obtained from the pasting curve. Pasting properties unit was expressed of cP.

The microstructural properties of noodle sheets were determined using SEM (S4800EDS; Hitachi Ltd., Tokyo, Japan). The samples were freeze dried and mounted on aluminum stubs using double-sided tape, and coated with a thin film of gold. The microstructures of the cutting plane were analyzed via SEM at a magnification of 5000 ×.

2.5. Evaluation of the quality of fresh noodles

Fresh noodles were prepared in accordance with the methods of Baik, Park, Paszczynska, and Konzak (2003) and Lee and Kang (2016). The thickness and color value of the noodle sheets, turbidity of boiled noodle water, and textural properties of cooked noodles were evaluated. The thickness and color values of the noodle sheets were measured using a Model G Peacock dial thickness gauge (Ozaki Mfg Co., Ltd., Tokyo, Japan) and a spectrophotometer (CM-5; Konica Minolta Inc., Tokyo, Japan), respectively. The noodles were boiled in water (500 mL) at 100 °C for 5 min. Thereafter, the noodles were immediately cooled in water at room temperature, and the absorbance of the boiled water was determined at 675 nm as the turbidity value using a UV-spectrophotometer (UV-1800; Shimazu Co., Tokyo, Japan). A spectrophotometer (CM-5, Konica Minolta, Osaka, Japan) was used to analyze lightness (L^*), redness (a^*), and yellowness (b^*) values of the samples. Calibration was performed with zero and white calibration. Color of the sample was measure of reflectance with specular component exclude using D65 light source. The textural properties of cooked noodles were investigated within 3 min after boiling. Textural analysis of the samples was performed using a texture analyzer (TA1; Lloyd Instruments Ltd., Fareham, UK) equipped with a 500 N load cell. The texture profile was analyzed with sample compression (five noodle strands) to 70% of the sample height at a crosshead speed of 10 mm/min with a cylindrical stainless steel 20 mm probe.

2.6. Statistical analysis

Data were obtained from three independent experiments and expressed as mean ± standard error of mean (SEM) values. The differences among samples were determined using ANOVA with SAS software (version 7.0; SAS Institute Inc., Cary, NC, USA). The P value between mean values was identified at the 5% probability level using Duncan's post hoc tests.

3. Results and discussion

3.1. Approximate composition and WHC of the samples

Moisture, crude ash, crude protein, crude fiber contents, and WHC of LW and oat flour blends are provided in Table 1. The moisture content of BO50, BO85 with 20% oat concentration was 11.15% and 12.32%, respectively, and the moisture content decreased with increasing oat flour concentration. In addition, the moisture content of samples treated at 150 MPa was not different from that of the control (12.30%); however, the moisture content of samples treated at 300 MPa (11.89%) was lower than that of the control. Crude ash, crude protein, and crude fiber contents of the blends increased with the addition of oat flour. Crude ash and crude fiber contents of BO50 were higher than those of BO85. The crude fiber of samples treated with 150-MPa was decreased. The crude protein content of BO50 and BO85 was 8.48% and 8.85%, respectively, and it was higher than that of LW alone (7.67%). However, the crude protein content was not influenced by HHP ($p < 0.05$). In the present study, dry gluten contents of commercial wheat flour and wheat with 20% oat flour were 10.00% and 8.35%, respectively (data not shown). Ahmed, Mulla, Arfat, and Kumar (2017) reported that application of high hydrostatic pressure of up to 600 MPa did not significantly affect moisture, protein, fat, or starch contents of post-processed samples irrespective of the flour-water ratio. However, Sheng et al. (2017) reported that soluble dietary fiber significantly increased while insoluble dietary fiber decreased compared with those of the control, and that the ratio between insoluble and soluble dietary fiber decreased in the HHP group. Similarly, we observed that crude fiber content in 150 MPa HHP-treated samples was lower than that in LW except LW treated 300 MPa. Xie et al., (2017) reported that high pressure (200 MPa) treatments effectively increased soluble dietary