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Utilisation of immature wheat flour as an alternative flour with antioxidant activity and consumer perception on its baked product

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ABSTRACT

The purpose of this study was to investigate the utilisation of immature wheat flour (IWF) as an alternative flour with antioxidant activity. Antioxidant properties and phenolic acid compositions of IWF and IWF madeleine were compared with those of commercial wheat flour (WF) and WF madeleine. Consumer perception of madeleine was studied using a blind test followed by an informed test, which provided information on antioxidant properties of flours. The bound ferulic acid in IWF (5.54 mg/100 g) was seven times higher than that in WF (0.74 mg/100 g). Oxygen radical absorbance capacity of IWF (34.47 μmol TE/g) and IWF madeleine (14.63 μmol TE/g) were higher than those of WF. The results of blind test showed that consumer acceptability and willingness to pay (WTP) of IWF madeleine were lower than those of WF madeleine. However, about 25% of consumers preferred IWF madeleine, implying small niche market for IWF as alternative flour.

1. Introduction

Wheat (*Triticum aestivum* L.) is the primary grain consumed globally as staple foods and has potential benefits for human health. Consumption of whole wheat products provides a lot of dietary fibre, vitamins, minerals, and antioxidant phytochemicals (Shahidi & Chandrasekara, 2015, chap 17). Considering health beneficial effects on wheat, several studies reported antioxidant potential of wheat or its bran (Okarter, Liu, Sorrells, & Liu, 2010; Van Hung, 2016). The antioxidant activities in wheat or its bran were closely associated with phenolic acids such as ferulic acid, *p*-coumaric acid, syringic acid, vanillic acid and caffeic acid (Okarter et al., 2010). These phenolic acids play an important role in the prevention of oxidative stress related disease such as cancer and cardiovascular disease (Van Hung, 2016).

Recent concerns about food or ingredient that improve health have promoted consumers to consider the consumption of antioxidant rich foods as one way to improve health. For these reasons, bakery product with improved antioxidant properties is another challenge for the food market and has been studied by many researchers (Bagdi et al., 2016; Kim, Lee, Do, & Bang, 2015; Sharma & Gujral, 2014; Varastegani, Zzaman, & Yang, 2015). Varastegani et al. (2015) and Sharma and Gujral (2014) reported that the utilisation of alternative flours that contain abundant phenolic compounds in baked products might be an effective means for the development of functional foods. Although previous studies have reported beneficial health effects of bakery products that contain antioxidant compounds, no information is available on antioxidant properties of bakery products made with immature wheat flours (IWF).

Immature wheat is typically obtained by early harvest when the wheat culms are still green in colour (Musselman & Al-Mouslem, 2001). Regarding changes of green immature wheat during maturation, Kim et al. (2007) reported that moisture, crude protein, crude lipid and ash contents of immature wheat were gradually decreased according to maturation. Similarly, Yang et al. (2012) reported that immature wheat grain contains less starch and protein and more fibre, essential amino acids and soluble sugar than mature wheat. Recent studies reported that the antioxidant and antiproliferative properties of immature wheat kernel or its bran were higher than those of mature wheat kernel and its bran (Kim & Kim, 2016; Kim, Yoon, & Kim, 2016). Also, few studies have reported physicochemical and nutritional properties of cereal based products such as bread (Mujoo & Ng, 2003), biscuits (Casiraghi et al., 2011), pasta (Casiraghi et al., 2013), tarhana (Aktas, Demirci, & Akin, 2015) prepared with flour partially replaced with IWF. In those studies, IWF was partially used to prepare cereal based products due to insufficient formation of gluten network of IWF. Katagiri, Masuda, Tani, and Kitabatake (2011) reported that IWF is not suitable for yeast leavened products such as bread, which need gluten network. However, IWF could be uti-

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lized for chemically leavened products, which don't need formation of gluten network as much as yeast leavened products. Although previous studies reported beneficial health effect of immature wheat and nutritional values of products made of partial replacement of IWF, no information is available on the bakery products made of only IWF and change of antioxidant properties induced by baking.

Currently the IWF or bakery products made with IWF are not available in the marketplace yet. The purpose of this study was to investigate the market opportunity of IWF as alternative flour by comparing with commercial wheat flour (WF). In this study, IWF was compared with WF by preparing madeleine, which was selected as one of the popular chemically leavened baked products. The antioxidant properties and phenolic acid compositions of IWF and IWF madeleine were analysed to identify functional benefits. Consumer perceptions such as acceptability and willingness to pay (WTP) were evaluated to investigate market opportunity for IWF as an alternative flour using madeleines.

2. Materials and methods

2.1. Materials

2.1.1. Flour samples

A commercial wheat flour (WF) and immature wheat flour (IWF) used in this study were identical wheat cultivars (*Triticum aestivum* L. cv. Keumkang), which were harvested in 2015. The WF was provided by CJ Jeiljedang Corporation (Seoul, Korea). The immature wheat was harvested using a combine harvester (Yanmar-AW695, Okayama, Japan) on 28th days after the heading date. Harvested wheat was dried overnight using a drying oven (HK-D0100F, Hankuk General Equipment Plant, Hwaseong-si, Korea). The dried immature wheat was milled into flour using an air classifying mill (SM500, Shin Myung High Tech., Siheung, Korea) equipped with an 80 mesh sifter. The bran (particle size > 177 μm) was separated by the sifter, and the resulting flour yield of the immature wheat was approximately 65%. The flour was packaged in a vacuum-sealed bag and stored at 0 °C until used.

2.1.2. Chemicals

Folin-Ciocalteu, Trolox, quercetin, 2,2′-azino-bis (3-ethylbenzo thiazoline-6-sulfonic acid (ABTS), fluorescein (FL), trifluoroacetic acid (TFA), gallic acid, catechin, vanillic acid, caffeic acid, syringic acid, *p*-coumaric acid, and ferulic acid were purchased from Sigma-Aldrich, Inc. (St. Louis, MO, USA). Monopotassium phosphate, dipotassium phosphate, ethanol, methanol, ethyl acetate, hydrochloric acid, sodium hydroxide, aluminium chloride, sodium carbonate, potassium persulfate, and hexane were obtained from Junsei Chemical Co., Ltd. (Tokyo, Japan). Sodium nitrite and 2,2′-azobis (2-amidinoprpane) dihydrochloride solution (ABAP) were purchased from Wako Chemicals Inc. (Richmond, VA, USA).

2.2. Methods

2.2.1. Proximate compositions, particle sizes, and colour characteristics of IWF and WF

The protein, ash, lipid, and total dietary fibre (TDF) contents of IWF and WF were measured using the AACC methods 46–12, 08–01, 30–25, and 32–05.01, respectively (AACC, 2000). The TDF content was analysed using a TDF-kit (Megazyme Inc., Chicago, Illinois, USA). The carbohydrate content was calculated according to the method described by Varastegani et al. (2015). In addition, particle size of flour samples was measured using a particle-size analyzer (1064, CILAS, Orleans, France). The colour characteristics (L, a, and b values) of flour samples were measured by a colorimeter (CR-300, Minolta, Tokyo, Japan).

2.2.2. Preparation of madeleine

As ingredients for preparation of madeleine, flour (28.13%), sugar (20.53%), egg (25.32%), butter (25.32%), and baking powder (0.7%) were used. The sugar, egg and butter were mixed using a Hobart mixer (KitchenAid K5SS, Benton Harbour, MI, USA) for 2 min at speed 6. Then, the flour and baking powder were added to the mixture and mixed for 3 min at speed 8. Approximately 19 g of the mixture was transferred to each madeleine mould, and baked for 12 min at 180 °C in an oven (Daeyung Bakery Machinery Co, Seoul, Korea), then cooled at room temperature. The consumer tests and the analyses of colours and textures of the madeleines were performed on the day of baking.

2.2.3. Colour characteristics and texture profile analysis of the madeleines

The colour values (L, a, and b) for the crusts of madeleines were measured using a colorimeter (CR-300, Minolta, Tokyo, Japan). The texture profile analysis (TPA) was performed by measuring springiness, cohesiveness, adhesiveness, hardness, and chewiness using the 2-bite compression test, as described by Casas Moreno et al. (2015). Two layers of madeleine crumb were compressed (50%) twice with a plunger (35 mm diameter) at a crosshead speed of 1.7 mm/s using a texture analyser (TA-XT 2, Stable Micro Systems Ltd., Haslemere, England).

2.2.4. Preparation of free and bound phenolics

The free and bound phenolics of flours, batters, and madeleines were extracted as soluble and insoluble phenolic fractions according to the procedure described by Kim and Kim (2016). The batters and madeleines were freeze-dried and then ground into powders using a Cyclotec™ 1093 sample mill (Foss, Hillerod, Denmark). The batter and madeleine powders were defatted with hexane and then were extracted as soluble and insoluble phenolic fractions. Each extract was concentrated using a nitrogen evaporator (model, company, city, country). The extracts were used for the measurements of the total phenolic content (TPC), total flavonoid content (TFC), phenolic acid compositions, oxygen radical absorbance capacity (ORAC), and Trolox equivalent antioxidant capacity (TEAC).

2.2.5. Phenolic acid compositions

The individual phenolic acid compositions of flour samples were analysed as described by Wu, Hung, Qin, and Ren (2013). The separation of individual phenolic acid was performed using High Performance Liquid Chromatography (HPLC, Waters e2695 separation module, Waters Corporation, Milford, USA) consisting of a pump, an autoinjector, and an array detector (Waters 2998 photodiode array detector, Waters Corporation, Milford, USA). The chromatograph was performed using an YMC – Triart C18 column (4.6 mm × 250 mm, YMC Co., Ltd., Kyoto, Japan). The mixture of solvent A (HPLC water containing 0.05% TFA) and B (acetonitrile:MeOH:TFA = 30:10:0.05) was used as the mobile phase and delivered at a flow rate 1 mL/min with gradient program as described in Wu et al. (2013). The total run time was 60 min with 8 min delay between injections. Ten microliters of sample were injected and resulting peaks were monitored at 280 nm. The each peak acquired was processed using Empower software (Waters Corporation, Milford, USA). The identification of each peak was confirmed using the retention time and absorbance spectrum of each standard compound. The contents of phenolic acids were quantified using external calibration curves of each standard.