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Effects of Hulless Barley (*Hordeum Vulgare* L.) Cultivar on the Quality of Pan-breads from Barley and Wheat Flour Blends

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Abstract

Six hulless barley (*Hordeum Vulgare L.*) cultivar, including 3 normal, 2 waxy, and 1 colored-waxy, was used to substitute 20% of wheat flour for pan-bread making. Replacing 20% barley flour significantly increased β-glucan content, which ranged in 0.98-1.36% for normal, 1.65-1.67% for waxy, and 1.50% for colored-waxy barley, which are all higher than wheat flour (0.14%). Pasting viscosity of barley flour blends varied by barley type and cultivar, presenting that barley cv. Dapung (DP) had the highest peak viscosity of 170.1 RVU, whereas the lowest value was 80.2 RVU in "Jasujeongchal (JSJC)". Substitution of barley flour decreased the *Hm* and *H'm* value during dough fermentation and estimated a reduction of bread qualities compared to wheat bread. Bread loaf volume varied by barley type and cultivar, showing a slight decrease in loaf volume, but increase in crumb firmness compared to wheat bread. Among barley cultivars, DP barley showed high bread loaf volume (691.7 cm^3/g) with lower firmness (11.8 N). In contrast, bread made from JSJC barley flour had the lowest bread-making qualities probably due to bran layer inclusion. It appeared that barley type influenced more than barley cultivars although the mean values of all quality parameters slightly varied by barley cultivar. Results indicated that the inclusion of barley flour for bread-making could provide an elevated intake of β-glucan, which had health benefits by increasing dietary fiber content.

Key words: barley flour, β-glucan, composite flour, bread quality

Introduction

Barley has gained an increased attention focused on dietary fiber and their health benefits. The β-glucan in the form of (1→3)(1→4)-β-glucans, major fiber constituents of barley, are considered as having important positive health impacts, being emphasized in coronary heart disease, cholesterol lowering effect, and reducing the glycaemic response (Jadhav et al., 1998; Brennan and Cleary, 2005). Barley (*Hordeum Vulgare* L.) genotypes are classified as hull-less and hulled (malting) barley. Hull-less barley cultivar was reported to have high content of protein, starch and β-glucans, compared to malting barley (Bhatty, 1999). Hull-less barley is used in human consumption in variety food forms. In Korea, barley is used mainly a rice substitute or extender, soups, and ingredients for bakery products to increase dietary fiber and β-glucan. Incorporation barley flour into foods has been proven diverse results depending on the type of food and the amount of barley flour used (Lee & Chang, 2003; Jeong & Ji, 2013).

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Wheat is the most suitable crop for making yeast-leavend breads and other baked products due to its protein compositions of glutenin and gliadin that gives bread dough its desirable viscoelastic properties (Morita et al., 1998). Wheat flour is one of good sources of calories and other nutrients, but in general white wheat flour is considered nutritionally poor. Thus, supplementation of inexpensive staples, such as cereals and legumes, in white wheat products has been focused in improving the nutritional quality, which contributes to enhance mineral, vitamins, protein or dietary fiber contents in the end-products (Sharma et al., 1999; Škrbić et al., 2009). Rizk et al. (2006) reported that substitution 10-30% of white wheat flour with barley flour for cake-making gave acceptable sensory properties evaluated by consumer subjects. Berglund et al. (1992) evaluated the end-use qualities of breads with 26% waxy barley flour for bread-making, and reported that the barley bread was comparable to those with 26% whole wheat flour, but higher in β-glucan content.

Barley genotypes and growing environment affects the compositions of barley grains, such as β-glucan, dietary fiber contents and various quality characteristics, which might give useful information with respect to their final utilization purpose (Lehtonen & Aikasalo, 1987). Consequently, the aim of this work was to observe the effect of partially substituting wheat flour with barley flour on pan-bread qualities, and to evaluate the bread characterization of various barley cultivars.

Materials and Methods

Barley and wheat plants

Six Korean barley cultivars were selected based on their genetically different barley types, which include 3 normal barley (Sasssal (SS), Dapung (DP), Dasong (DS)), 2 waxy barley (Hinchalssal (HC), Pungsanchal (PSC)), and 1 colored-waxy barley (Jasujeongchal (JSJC)). The wheat cultivar Keumkang (KK) was used as the base flour for blending barley and wheat flour. They were grown at the research field in the National Institute of Crop Science (NICS), RDA, during 2012-2013 growing season. The normal and waxy barley grains were pearled to 77% level, which was a commercial scale, and the colored-waxy barley grain were pearled to 97% level. As the purple pigment of JSJC is existed in the outer layer of grain, the pearling ratio was determined as 97% to keep in the blend. The pearled barley grains were milled using a hammer mill (laboratory mill 3100, Pertent Co., Ltd., Huddings, Sweden) equipped with 0.5 mm screen and operated at 16,800 rpm. For wheat flour milling, the moisture content of KK grains was adjusted at 16% and tempered overnight. Wheat grain (2.0 kg) was milled with a Bühler mill (MLU-202, Bühler Brothers, Uzwil, Switzerland). White wheat flour was collected and used to prepare the barley and wheat flour blend for its flour characterization and pan-bread making.

Composite flour preparation and chemical analysis

The blends of barley and wheat flour were prepared by substituting white wheat flour with barley flour from various cultivars at 20% level. The effects of barley cultivar in the blends were evaluated for chemical compositions. Ash content was determined according to the AACC official method 08-01 (AACC 2000). Protein contents were measured by the total nitrogen contents (N 5.7) using an elementar analysis (2410 nitrogen analyzer, Perkin Elmer, Waltham, MA, USA). The β-glucan content of composite flour was determined according to the AACC official method 32-23 (AACC 2000), using an enzymatic assay kit (Enzymatic β-glucan assay kit, Megazyme International Ireland Ltd., Bray, Ireland).

Pasting properties of the composite flour

Pasting properties were measured by a Rapid visco analyzer (RVA-4, Newport Scientific Pty. Ltd., Warriewood, Australia) in accordance with the AACC official method 61-02 (AACC 2000). Samples were prepared by mixing 3.0 g of composite flour in 25 ml distilled water in an aluminum canister, to which a paddle was placed. Testing conditions for wheat flour pasting viscosity were applied, and those parameters include heating and cooling rates of 12 ^{o}C/min, over a temperature range of 50^{o}C to 95^{o}C, with paddle speed of 160 rpm. Pasting characteristics of peak viscosity [PV], breakdown viscosity [BD] and final viscosity [FV] were determined.

Preparation of pan-bread

Test breads were baked with the 100 g composite flour according to a basic straight dough method of AACC official method 10-10A. All the ingredients were mixed with optimum water and mixing time, which was adjusted by 10 g mixograph (National Mfg. Co., Lincoln, NE, USA) determination (AACC 54-40A). Bread dough was prepared using a 100 g pin-type mixer (National Mfg. Co., Lincoln, NE, USA), then fermented in a cabinet fermenter (model FP201, Daeyoung Co., Seoul, Korea) at 30^{o}C and 85% relative humidity (RH). A dough molder (model DYM 2001, Daeyoung Co., Seoul, Korea) was used for sheeting and molding purpose. After proofing, baking was done in an electrical deck oven (DYM FDO 7102, Daeyoung Co., Seoul, Korea) at 210^{o}C for 24 min. The baked breads were cooled at room temperature for 2 hr for further analysis. Bread samples for analysis were prepared in duplicate.

Bread dough and end-use quality evaluation

Bread dough development was measured according to the method by Czuchajowska and Pomeranz (1993). A rheofermentometer (Chopin Fe; Chopin Technologies, Villeneuve-La-Garenne Cedex, France) was used to measure 2 parameters of dough development, which includes maximum height of dough (*Hm*, mm) and maximum height of gaseous release (*Hm'*, mm). The 100 g dough was placed in a movable basket of the gas meter with a 2 kg cylindrical weight, and the cover of the vat was fitted with an optical sensor. The measurement was conducted at 30^{o}C for 3 hr. The end-use quality of baked bread was conducted with the cooled bread loaf. The bread loaf volume was measured with a bread loaf volumeter (National Mfg. Co., Lincoln, NE, USA) using rapeseed displacement method in a graduated chamber (AACC 10-05.01).

Bread crumb firmness was determined by a compression method using a texture analyzer (TA-XT2, Stable Micro System Ltd., Haslemere, UK). The bread loaves were sliced into 1.3 cm thick and used immediately for the compression test. Two bread slices were placed on a flat metal plate, and compressed to a total compression of 40% using a flat aluminum plunger with a diameter of 35 mm. The maximum peak force (g) in compression was recorded as firmness of bread crumb. The whole procedure was repeated on 5 different sets of bread slices, and the firmness values were averaged. The color parameters of L^*, a^*, b^* of bread crumb were measured using a color difference meter (color JS-55, Color Technology System Co., Tokyo, Japan) in triplicate.

Statistical analysis

Date analysis results were reported as a mean obtained from at least duplicate measurements of samples. Analysis of variance (ANOVA) of the results was performed using the SAS statistical software (Version 9.1, SAS Institute Inc., Cary, USA). The significance of differences, observed among sample means, was established using Tukey's Studentized range test at $p<0.05$.

Result and Discussion

Chemical composition analysis

The chemical compositions of composite flour are presented in Table 1. The ANOVA (F-value) shows that barley flour significantly affected the compositions of ash, protein and β-glucan of the composite flour of barley and wheat flour. Substituting 20% barley flour increased ash content regardless of barley type - normal, waxy, and colored-waxy barley - compared to wheat flour of KK, noting that the blends with colored-waxy barley JSJC, which was not pearled, shows significantly higher ash contents of 2.68%. The protein content was the least in the blends with normal barley cultivar ranging 13.36-13.57%, followed by waxy and colored-waxy barley of 13.77-13.78% and 14.07%, respectively. The higher protein of colored-waxy blends could be derived from the inclusion of outer layer of grains in which higher protein contents were presented. Substituting wheat flour with barley flour at 20% significantly increased the β-glucan content, being ranged in 0.98-1.36% for normal barley flour, 1.49-1.67% for waxy barley, and 1.50% for colored-waxy barley. Waxy-type barley cultivar leads to more increment of β-glucan content compared to normal barley. A significant lower β-glucan was found in wheat flour (0.14%). Results indicated that chemical properties varied among the barely flour blends, being influenced more significantly by barley type than cultivars.

Pasting properties and dough fermentation analysis

The pasting characteristics of composite flour are presented in Table 2. The ANOVA (F-value) indicates a significant effect of barley flour on RVA pasting parameters at $p<0.01$. Results showed that the peak viscosity (PV) development increased in normal barley flour ranged from 135.6 to 170.1 RVU, but decreased in waxy and colored-waxy cultivar ranged from 110.0 to 121.9 RVU. The PV of wheat flour was measured as 131.2 RVU. The decreased PV of composite flour with waxy barley cultivar might be due to the higher β-glucan content, resulting in lower pasting properties. No significant difference in pasting properties by barley cultivar was found within the same barley type. Thus, it could be explained that barley type affected more significantly than barley cultivar on pasting properties.

Studies reported that increasing addition of β-glucan in starch mixture resulted in increasing peak viscosity (Zhou et al., 2000; Colleoni-Sirghie et al., 2004), noting that soluble β-glucan content mostly contributed to the viscosity of barley flour over 29 barley varieties (Izydorczyk et al., 2000). Symons and Brennan (2004) observed a decreased pasting viscosity in the wheat flour blends with a β-glucan rich

Table 1. Compositions of barley and wheat flour blends

Barley-type	Cultivar	Ash(%)	Protein(%)	β-glucan(%)
Normal	SS	$0.91±0.01^{c}$	$13.57±0.04^{bc}$	$1.36±0.03^{bc}$
	DP	$0.79±0.02^{d}$	$13.36±0.15^{c}$	$0.98±0.01^{d}$
	DS	$0.74±0.01^{e}$	$13.48±0.01^{bc}$	$1.21±0.02^{c}$
Waxy	HC	$1.09±0.01^{b}$	$13.77±0.13^{ab}$	$1.65±0.05^{a}$
	PSC	$0.76±0.01^{e}$	$13.78±0.09^{ab}$	$1.67±0.07^{a}$
Colored-waxy	JSJC	$2.68±0.02^{a}$	$14.07±0.01^{a}$	$1.50±0.01^{b}$
Wheat	KK	$0.47±0.01^{f}$	$14.04±0.08^{a}$	$0.14±0.02^{e}$
ANOVA (F-value)		8274.54^{***}	19.28^{***}	467.98^{***}

$^{a-f}$Values with different letters in the same column are significantly different at $p<0.05$.
***Significant at $p<0.01$.
Barley: Saessal (SS), Dapung (DP), Dasong (DS), Hinchalssal (HC), Pungsanchal (PSC), Jasujeongchal (JSJC), Wheat : Keumkang (KK).

Table 2. Pasting-properties and bread dough fermentation of barley and wheat flour blends

Barley-type	Cultivar	Pasting viscosity (RVU)					Dough fermentation	
		Peak V.	BD V.	Final V.	Time (min)	Temp (°C)	*Hm* (mm)	*H'm* (mm)
Normal	SS	135.6 [ab]	59.9 [ab]	147.4 [bcd]	5.97 [a]	65.70 [a]	17.4 [d]	91.4 [a]
	DP	170.1 [a]	67.9 [a]	199.0 [a]	6.04 [a]	64.45 [a]	24.5 [b]	83.2 [b]
	DS	151.6 [ab]	67.2 [a]	165.2 [abc]	5.90 [a]	64.55 [a]	23.8 [b]	66.9 [e]
Waxy	HC	110.0 [bc]	50.5 [abc]	119.3 [de]	5.87 [a]	63.68 [a]	20.7 [c]	66.6 [e]
	PSC	121.9 [bc]	59.4 [ab]	125.1 [cde]	5.87 [a]	63.75 [a]	20.0 [c]	73.9 [d]
Colored-waxy	JSJC	80.2 [c]	38.4 [bc]	88.2 [e]	5.47 [b]	66.95 [a]	12.6 [e]	75.9 [c]
Wheat	KK	131.2 [ab]	36.3 [c]	181.1 [ab]	5.93 [a]	65.40 [a]	39.9 [a]	83.0 [b]
ANOVA (F-value)		21.09***	17.14***	35.82***	17.65***	1.01	765.34***	1124.44***

[a-e]Values with different letters in the same column are significantly different at $p<0.05$.
***Significant at $p<0.01$.
Barley : Saessal (SS), Dapung (DP), Dasong (DS), Hinchalssal (HC), Pungsanchal (PSC), Jasujeongchal (JSJC), Wheat : Keumkang (KK).

fraction of 2.5 and 5.0%, and reported that the reduced available water within the paste mixture due to the preferential hydration of β-glucan rich fraction would limit the swelling of starch granules within the pastes, in turn leading to retention of starch granule integrity resulted in gelatinization. Zhang et al. (1998) reported that the non-starchy polysaccharides such as β-glucan affected the pasting properties of barley flour.

The breakdown (BD) viscosity showed that incorporation of barley flour at 20% level formed less stable hot paste than wheat flour. In addition, the final viscosity (FV) of normal barley flour mixture was significantly higher than the other samples. There was no significant difference in gelatinization time and temperature. But, it was found that colored-waxy barley flour showed a reduced gelatinization time, but an increased temperature compared to other barley mixture samples. The reduced viscosity in the blends with waxy barley flour would be due to high β-glucan content of waxy barley, which in turn affected lower viscosity.

Dough fermentation properties were measured by *Hm*, the height of maximum dough development, and *H'm*, the height of maximum gas formation during fermentation. A decrease in the *Hm* value was observed in the dough from composite flour blends (12.6-24.5 mm) compared to wheat flour (39.9 mm). The *Hm* value ranged in 17.4-24.5 mm for normal barley, 20.0-20.7 mm for waxy, and 12.6 mm for colored-waxy barley. It indicated that the bread-making property of colored waxy barley flour in which bran layer was included was inferior to normal and waxy-barley flour for pan-bread making. In addition, it was observed that *Hm* and *H'm* values of barley cv. Dapung (DP) was higher than the other barley flour mixtures.

Huang et al. (2008) reported that a higher *Hm*, an indirect estimation of yeast performance and overall microstructure of bread system, indicates that the combination of gas production and dough microstructure is more favorable to final bread volume. The *H'm* value was also lower in the dough from

Table 3. End-use qualities of pan-breads from barley and wheat flour blends

Barley-type	Cultivar	Quality characteristics of breads					
		loaf V. (cm^3/g)	loaf SV.	Firmness (N)	L	a	b
Normal	SS	666.7[b]	4.6[b]	13.7[bc]	63.8 [b]	-0.3[c]	18.9[a]
	DP	691.7[b]	4.8[b]	11.8[c]	62.3[b]	-0.1[b]	17.3[bc]
	DS	688.3[b]	4.7[b]	12.6[bc]	63.9[b]	-0.2[c]	17.5[bc]
Waxy	HC	650.0[bc]	4.5[b]	13.9[b]	62.9[b]	-0.3[c]	18.1[ab]
	PSC	675.0[b]	4.5[b]	11.9[bc]	63.4[b]	-0.3[c]	17.5[bc]
Colored-waxy	JSJC	608.3[c]	4.2[c]	18.6[a]	53.6[c]	1.9[a]	17.5[bc]
Wheat	KK	783.3[a]	5.6[a]	5.3[d]	68.9[a]	-1.9[d]	16.7[c]
ANOVA (F-value)		35.52***	37.04***	52.51***	145.91***	1600.88***	7.77***

[a-d]Values with different letters in the same column are significantly different at $p<0.05$.
***Significant at $p<0.01$.
Barley: Saessal (SS), Dapung (DP), Dasong (DS), Hinchalssal (HC), Pungsanchal (PSC), Jasujeongchal (JSJC), Wheat : Keumkang (KK).

waxy barley flour blends ranging in 66.6-75.9 mm, whereas *H'm* value of normal barley blends ranged from 66.9 to 91.4 mm, which varied significantly among barley cultivar. The *H'm* value of wheat flour was determined as 83.0 mm.

Baked pan-bread quality

Table 3 presents the end-use qualities of breads from the barley composite flour, comparing to wheat bread. The ANOVA (F-value) shows that barley flour significantly affects the bread loaf volume and bread crumb firmness. Replacing barley flour for white wheat flour resulted in a decrease in bread loaf volume. Breads from composite flour exhibited firmer bread crumb texture compared to white bread as the control. Bread loaf volume ranged 666.7-691.7 cm^3/g for normal barley, 650.0-675.0 cm^3/g for waxy-barley, and 608.3 cm^3/g for colored-waxy barley flour blends. Based on Tukey's multiple comparisons, there was no significant difference statistically between breads with normal and waxy-type barley cultivar, but differed ($p<0.05$) with colored-barley flour. Similarly to the results of dough fermentation, the difference of colored-barley flour could be occurred due to the inclusion of outer layers of colored barley grain of JSJC. The bread crumb firmness varied among barley cultivar, indicating that colored-waxy barley bread was the most firm texture compared to other barley breads. Bread crumb color measured by *Hunter's* L, a, and b represented that inclusion of barley flour resulted in bread with slightly darker crumb. Also, comparing to the wheat bread, breads from barley composite flour tended to be slightly more red and yellow color.

Reduced loaf volume as consequence of substitution of barley flour to wheat flour formulation was observed by Škrbić et al. (2009) and Cleary et al. (2007). Additionally, Gill et al. (2002) investigated the effect of barley flour (regular and waxy) on bread quality, and reported that at 15% substitution, waxy barley bread has a significantly lower volume than regular barley bread. Symons and Brennan (2004) explained that the glucan component could tightly bind appreciable water in the dough, and making it less development of gluten network, which in turn would limit the expansion of bread dough, leading to a more compact loaf with a reduced loaf volume and increased firmness.

Substitution of 20% barley flour in white wheat flour significantly increased β-glucan content, which in turn affected the characteristics of pasting properties and bread-making qualities. Peak viscosity of normal barley was higher than other barley blends, showing "Dapung (DP)" showed the highest peak viscosity. Dough fermentation based on *Hm* and *H'm* values represented that bread-making properties of colored-waxy barley flour was inferior to normal and waxy-barley flour for pan-bread making due to the inclusion bran layer. Bread loaf volume varied by barley type and cultivar, showing a slight decrease in loaf volume, but increase in crumb firmness compared to wheat bread. Among barley cultivar, DP barley showed high bread characteristics in terms of dough fermentation and baked bread qualities. In contrast, the bread made from the composite flour with JSJC had the lowest bread-making qualities due to probably bran layer inclusion. Although, inclusion barley flour reduced the end-use qualities of pan-bread, substitution of wheat flour with barley flour could provide an elevated intake of β-glucan, which has health benefits by increasing fiber content.

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