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Influence of Extruded Hemp-Rice Flour Addition on the Physical Properties of Wheat Bread

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Abstract

Functional foods play an important role in daily diet, human health and the food industry. Hemp was reported to have many advantages for nutritional and medicinal usage. In this study, extruded hemp-rice (EHR) flour, containing 30% hemp, was mixed with the wheat flour to create bread loaves at the concentrations of 5, 10 and 15%. Bread made from 100% wheat flour (with no added EHR flour) was used as a control. The physical parameters, including expansion ratio, specific volume and crust/crumb color were evaluated separately. In addition, changes in hardness of the bread during storage at ambient temperature for 3 days were also studied. The results showed that 10%-EHR bread exhibited the highest hardness value, while 15%-EHR bread presented the lowest. The bread containing EHR flour had lower specific volume and bigger air cells compared to the control. Moreover, the crust and crumb color of EHR-containing bread was significantly darker than those of the control. In this study, the 15%-EHR bread showed higher specific volume, lower hardness and bigger air cell structures.

Key words: bread making, extruded hemp-rice, physical properties, hardness

INTRODUCTION

Hemp (*Cannabis sativa* L.), an annual herbaceous plant, has been grown agriculturally for many centuries for its fiber and oil. Non-drug varieties of hemp have not been studied extensively for their nutritional potential in recent years, nor has hempseed been utilized to any great extent by the industrial processes and food markets that have developed during the 20th century (1). Hempseed contains 20～25% protein, 20～30% carbohydrates, 25～35% oil, 10～15% insoluble fiber, and a rich array of minerals, particularly phosphorus, potassium, magnesium, sulfur, and calcium along with modest amounts of iron and zinc, the latter of which is an important enzyme co-factor for human fatty acid metabolism (2). Hempseed oil is composed of over 80% of polyunsaturated fatty acids (PUFAs), which include essential fatty acids, linoleic acid (18:2n6), and α-linolenic acid (18:3n3) as major components, as well as γ-linolenic acid (18:3n6) (1). These fatty acids are critically important for human health. Hempseed is also a good source of high-quality protein. The two main proteins in hempseed have been identified as edestin and albumin (3). Both of these high-quality storage proteins are easily digested and contain nutritionally significant amounts of all essential amino acids (1). Hempseed, in addition to its nutritional value, has demonstrated positive health benefits, including lowering cholesterol and high blood pressure (4). Consuming hemp seeds will enhance the immune system having the reservoir of immunoglobulin resources needed to produce disease-destroying antibodies (5).

Extrusion cooking as a critical technology has been most commonly used to produce various breakfast cereals foods. This type of preparation can improve ingredient utilization, reduce energy costs, and produce a nutritionally balanced product in an appetizing form (6), and also can improve dietary fiber nutritional quality (7). Nevertheless, productions made from extruded hempseed flour as well as their corresponding evaluation were little to be investigated. Due to their high fat content and the fat's powerful lubricant effect in extrusion cooking, it is difficult to use hempseeds alone to produce the extruded hempseed flour. Therefore, starch must also be added to improve extrusion ability and product properties. Generally, rice flour is the best choice as a result of its white color and a bland taste that should not cover the typical flavor of hempseed.

With appropriate formula modification and/or process optimization, many kinds of bread with acceptable qualities can be made by adding non-traditional ingredients. A variety of wheat flour substitutions have been tried in bread formulations with varying success. In this study, wheat flour substituted with different levels of extruded hemp-rice (EHR) flour was used to make bread. The objective of this study was to examine the influence of

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EHR flour on the physical quality of bread.

MATERIALS AND METHODS

Materials

Wheat flour, rice flour and hemp seeds were purchased from local markets in Korea. Hemp seeds were ground into fine powder, blended with rice flour at a 3:7 (hemp: rice) ratio, and then extruded using a twin-screw extruder (THK31T, Incheon Machinery Co., Incheon, Korea) equipped with a 32-mm diameter at a 24:1 L/D (length to diameter) ratio. Extrusion was performed with barrel temperature at 120°C, moisture content of 20%, screw speed 200 rpm, feed rate 120 g/min and die diameter 3 mm. After extrusion, the sample was dried in an oven at 50°C for 8 hr and ground into fine powder. Then the powder was sieved through a 30-mesh screen, and stored in sealed plastic bags.

Bread making

Wheat flour was substituted with EHR flour at 5, 10, and 15% levels to make bread according to straight dough method. Wheat bread without EHR flour was used as a control. The bread formulation per 100 g bread flour was: 10 g sugar, 1.5 g salt, 1.5 g yeast, 6.7 g butter and 60 g water. Briefly, dry flour and sugar sieved twice were placed in the mixer. Yeast dissolved in 30～40°C water (yeast : water = 1:5) was added to the dry ingredients together with dissolved salt. All the ingredients were mixed for 5 min at Speed-1 in the mixer. Then, the butter was put into the mixer. When the butter mixed well with the dough, the speed of mixer was changed to Speed-2 for another 15 min. Then the dough was fermented in an incubator at 30°C. After 60 min, the dough was punched down to remove gases and divided into pieces with a weight of 350 g for each. Each piece was shaped, and placed in the bread baking tin (21.5×10 cm^2 in top, 19.5×8.5 cm^2 in bottom, and 9.5 cm in depth), with three pieces for each tin. Then dough proofed at the same incubation conditions for 40 min. Proofed loaves were baked at 160°C for 50 min in oven. The baked bread was cooled at ambient temperature for 2 hr before analysis.

Dough expansion ratio

Expansion ratio of dough was determined by the ratio of bread volume before and after fermentation. Dough pieces (30 g) were carefully placed in sterilized cylinder and the volume was recorded. After fermented at 30°C for 60 min, the dough volume in cylinder was also recorded. Three replications were measured for each sample and the means were reported.

Determination of bread physical properties

Specific volume: The specific volume was measured with mass displacement method (millet seed) as proposed by Lopez et al. (8) with minor modifications. The millets were poured into a container with known volume, until about one-fourth of the container height. Then, the bread was weighed with a digital balance (0.01 g accuracy) and then placed in the container. The millet was then added to fully fill the container and the excess millet was scraped out. The containers containing bread and millet were weighed. Specific volume was defined as the mean volume (cm^3) of the sample divided by weight (g). Measurements were performed in triplicate for each sample.

Crust and crumb color: The crust and crumb color were measured using a handheld chroma meter (CR-300, Minolta, Osaka, Japan), as described by Koca and Anil (9). The color parameters L (black to white), a (redness to greenness), and b (yellowness to blueness) were separately recorded. The top crust was divided equally into three regions and the parameters L, a, b were determined at five points within each region. Bread was sliced carefully using a bread knife to obtain uniform slices with 20-mm thickness. Two points in the center of each slice were selected to evaluate the crumb color. Total color difference (ΔE) was calculated as $\Delta E=(\Delta L^2+\Delta a^2+\Delta b^2)^{1/2}$, using bread color of the control as a reference.

Bread hardness: The bread samples were cut into cubes with a size of $2.5\times2.5\times2.0$ cm^3 and then packaged in polyethylene bags. Each batch of cubes was kept at ambient temperature for 3 days. The hardness analysis was performed in an interval of 24 hours using a compression test by a Sun Rheometer (Compac-100 II, Sun Sci. Co., Tokyo, Japan) equipped with a 10-kg load cell and a 25-mm aluminum cylindrical probe. Each cube was compressed to 40% of its original height at a crosshead speed of 120 mm/min.

Statistical analysis

All statistical was analyzed using SAS version 9.1 (SAS Institute Inc., Cary, NC, USA). Analysis of variance was performed by the General Linear Model procedure. Duncan's range test was used to detect significance of difference at $p<0.05$.

RESULTS AND DISCUSSION

Dough expansion ratio

The expansion ratio of the dough with and without EHR flour is presented in Fig. 1. Expansion ratio is an index of the expansion degree during fermentation, which can reflect the dough quality before and after fermentation (including two stages for mixing and fermentation). The expansion ratio value of the dough with 10%-EHR flour (1.83) was significantly lower than those

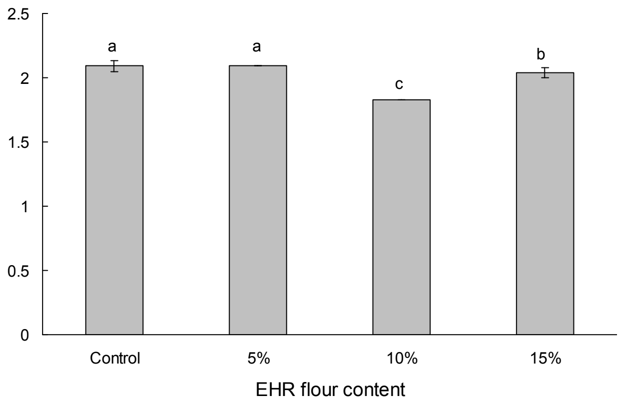

Fig. 1. Effect of different contents of extruded hemp-rice (EHR) flour on dough expansion ratio.

of the others, while expansion ratio values of the dough with 5%-EHR flour and the control did not show a significant difference. The dough expansion predominantly depends on the mixing and fermentation during bread making process. During mixing, the carbon dioxide is created from flour sugars by yeast and then diffuses toward air cells embedded in the dough (10). During fermentation, dough volume is increased both by the amount of carbon dioxide gas that is produced in this process and by increased fermentation times, as reported by Chevallier et al. (11).

Specific volume

The specific volume values of 5%, 10%, 15%-EHR bread and the control are shown in Fig. 2. The same variation pattern as that of the dough expansion ratio was observed. The specific volume of EHR-containing bread was lower than that of the control and decreased with increasing ration of EHR flour present in bread. Notably, the 10%-EHR bread revealed the lowest specific volume value. Compared to the control, the 5%-EHR bread showed no significant changes in specific volume. It was reported that partial replacement of wheat flour with non-glutinous flour has been shown to result in lower bread volume (12). Similar results were also reported in wheat-barley blends bread (7) and in wheat-whole waxy wheat blends bread (13). Non-glutinous rice flour present in EHR flour may dilute the gluten protein of wheat flour and prevent its extension. This phenomenon became more and more significant with the increasing levels of EHR content. However, the specific volume increased when the EHR flour ratio reached to 15%, which is presumed to result from the influence of fat. The fat content increased with increasing levels of EHR (data not shown). A similar result was also reported that the shortening effect of flaxseed fat content on dough can result in the best-quality bread in terms of loaf volume (9). Aini and Maimon (14) suggested that proper amount of fat in dough improves the volume, texture and crust tenderness, keeps the quality of bread high, and makes the dough more elastic.

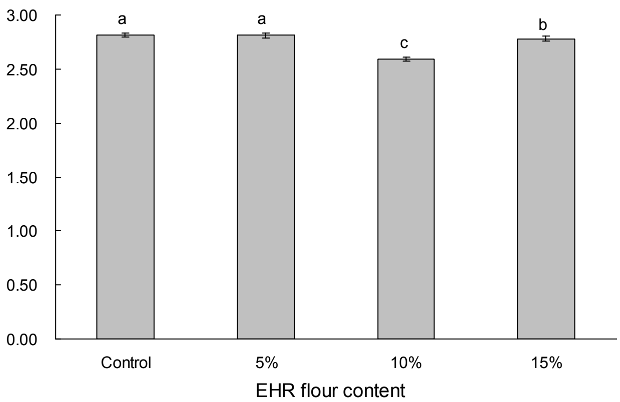

Fig. 2. Effect of different contents of extruded hemp-rice (EHR) flour on bread specific volume.

Crumb cross-sectional views

The cross-sectional views of EHR-containing bread crumbs are shown in Fig. 3. The air cells were bigger when EHR flour was present in the bread. In spite of lower specific volume, EHR-containing bread showed bigger air cell distribution. Furthermore, 15%-EHR bread displayed a higher specific volume as well as bigger air cell structure than 10%-EHR bread. Similar results were reported by Hung et al. (13) with commercial white flour and whole waxy wheat flour blends bread.

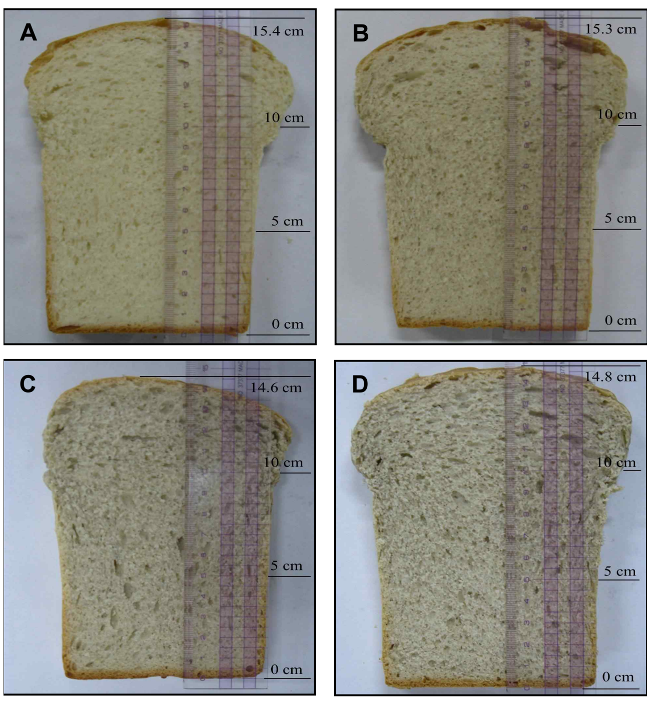

Fig. 3. Digital photographs of EHR-containing bread crumbs. (A) Control (B) 5%-EHR, (C) 10%-EHR and (D) 15%-EHR.

Table 1. Crust/crumb color values of EHR-containing bread

	Bread type	Color value			
		L	*a*	*b*	*ΔE*
Crust	Control	59.61±2.18^{a}	11.07±1.23^{a}	36.98±0.83^{a}	−
	5%-EHR	58.15±1.55^{b}	10.08±0.77^{b}	36.06±0.92^{b}	1.98
	10%-EHR	57.20±1.67^{bc}	8.69±0.91^{c}	33.99±0.87^{c}	4.51
	15%-EHR	56.12±1.92^{c}	7.75±1.07^{d}	32.50±1.03^{d}	6.58
Crumb	Control	73.33±1.47^{a}	-2.18±0.14^{d}	12.79±0.62^{b}	−
	5%-EHR	67.84±0.98^{b}	-1.53±0.14^{c}	12.41±0.37^{c}	5.55
	10%-EHR	64.56±1.82^{c}	-0.57±0.17^{b}	13.17±0.46^{a}	8.93
	15%-EHR	62.10±1.24^{d}	-0.46±0.14^{a}	13.30±0.51^{a}	11.37

Means in a column followed by the same letter are not significantly different by Duncan's multiple range test at $p<0.05$.

Crust/crumb color

Table 1 displays the color values of crust and crumb for the bread, respectively. Crust color was different between EHR-containing bread and the control. Crust *L*, *a* and *b* values were reduced significantly with increasing level of EHR content. The decrease in yellowness may be due to the fact that more fibers in hemp absorb sugars and the absorbed sugars are released slowly (15). Crust color darkened with increasing levels of EHR content. A similar tendency was observed by Koca and Anil (9) in flaxseed and wheat flour blend breads such that flaxseed flour reduced crust *L*, *a* and *b* values, and crust color darkened with increasing substitution level of flaxseed flour.

Crumb *L* value obviously decreased, but crumb *a* and *b* values increased with increasing EHR flour levels compared to that of the control, with the exception of the value of 5%-EHR bread, which showed no significant difference. Crumb darkness increased with increasing EHR flour levels. A similar tendency was observed by Siddiq et al. (12) in defatted maize germ and wheat flour blends bread, when the lightness *L* value significantly decreased with defatted maize germ flour addition, and *a* and *b* values increased significantly with defatted maize germ flour addition in bread formulations.

Bread hardness

The hardness values of bread samples over a 3-day storage period are plotted in Fig. 4. Crumb hardness values between 5%-EHR bread and the control were similar, and showed similar tendencies during the entire storage period. The crumb hardness value of the 10%-EHR bread was markedly higher than those of other bread during 3-day storage period, and it also showed a distinct increase in the first day by 96.71 g/cm^2. The 15%-EHR bread displayed a significantly lower hardness value (ranging from 181.44 to 321.51 g/cm^2 during 3-day storage) compared with other bread samples.

From the results described above, it can be easily inferred that the hardness value had a negative correlation with the specific volume value. The bigger loaves have less dense structure resulting in lower hardness, whereas smaller loaves have more dense structure resulting in higher hardness. Similar results were also reported on the influence of gluten-free flours and their mixture on batter properties by Sciarini et al. (16).

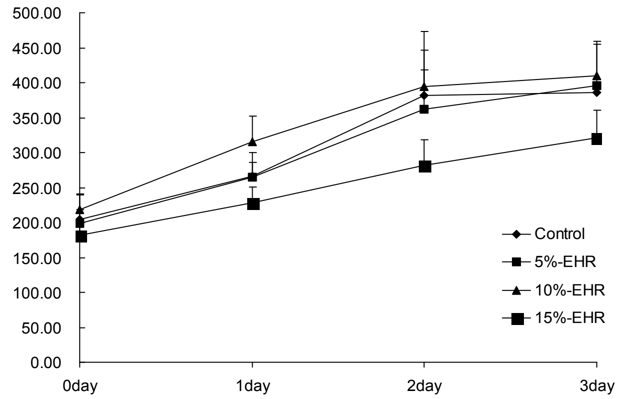

Fig. 4. Effect of different contents of extruded hemp-rice (EHR) flour on bread hardness during 3-day storage.

Correlation between bread quality attributes

In order to explore interactions between different quality attributes, a correlation analysis was carried out (12) as shown in Table 2. The specific volume of bread showed significantly positive correlation (0.999) with expansion ratio of the dough, and a negative correlation with crumb hardness (-0.670), crumb *a* (-0.620) and crumb *b* (-0.527). Accordingly expansion ratio of the dough also showed a negative correlation with crumb hardness (-0.642), crumb *a* (-0.644) and crumb *b* (-0.565). Moreover, crust *L*, crust *a* and crust *b* were highly correlated with each other. Crumb *L* showed negative correlation with crumb *a* (-0.976) and crumb *b* (-0.634). Crumb *L* showed significant positive correlation with crust color, while crumb *a* and crumb *b* showed negative correlation with crust color.

CONCLUSIONS

The expansion ratio of the dough and the specific vol-

Table 2. Correlation coefficient matrix for physical properties of EHR-containing bread

Property	Dough expansion ratio	Specific volume	Hardness	Crust-*L*	Crust-*a*	Crust-*b*	Crumb-*L*	Crumb-*a*	Crumb-*b*
Dough expansion ratio	1.000								
Specific volume	0.999	1.000							
Hardness	-0.642	-0.670	1.000						
Crust-*L*	0.419	0.391	0.411	1.000					
Crust-*a*	0.488	0.458	0.353	0.989	1.000				
Crust-*b*	0.467	0.434	0.377	0.974	0.995	1.000			
Crumb-*L*	0.480	0.456	0.332	0.994	0.979	0.954	1.000		
Crumb-*a*	-0.644	-0.620	-0.161	-0.964	-0.977	-0.960	-0.976	1.000	
Crumb-*b*	-0.565	-0.527	-0.106	-0.672	-0.773	-0.821	-0.634	0.742	1.000

ume of the bread showed similar tendencies of variance. The EHR-containing bread showed lower specific volume than the control. The specific volume of 10%-EHR bread was found to be the lowest in our experiments. The crust and crumb color of the control showed the most lightness in colorant test. The lightness of crumb and yellowness of crust was decreased with increasing levels of EHR flour. In this study, 15%-EHR bread showed higher specific volume, the lower hardness and the bigger air cell structure in these samples.

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