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ORIGINAL ARTICLE

Texture Properties and Radical Scavenging Ability of Porridge Products Based on Beans, Grains, and Nuts

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Abstract Textural and sensory properties and radical scavenging ability of rice and cereal-based porridges such as beans, nuts, and grains were examined. Textural properties of the porridges, including hardness, adhesiveness, cohesiveness, springiness, and gumminess, were determined using a TA-XT2 texture analyzer. For the sensory evaluation, thirty-five volunteers participated in the randomized incomplete block design. The 1-diphenyl-2-picrylhydrazyl method was carried out to determine the radical scavenging ability of the porridges. Cereal-based porridges added with beans, grains, and nuts appeared to be less hard and sticky than plain rice porridges. Overall sensory acceptabilities for black rice, walnut, and pine-nut porridges were higher than those for plain rice porridges. Pine-nut, walnut, grain porridge such as wild sesame, black rice, and mixed grains provide strong radical-scavenging ability compared to plain rice porridges. Our results suggest that cereal-based porridge prepared with beans, grains, and nuts are nutritious and palatable substitute food for people with chewing difficulty.

Keywords cereal based porridge · plain rice porridge · radical scavenging ability · sensory · texture

Introduction

Chewing is an important process of digestion by preparing food for swallowing and further processing in the digestive system (Pedersen et al., 2002). Chewing difficulty often results from physical changes to the mouth, jaw or tongue caused by tooth extraction, cosmetic surgery or aging. People with significant physical changes in and around the mouth consume fewer fruits, vegetables, and meat. These changes in diet puts individuals in a higher risk of malnutrition (Mojon et al., 1999; Sheiham et al., 2001), especially in elderly patients with severe functional impairment comprising lower body mass index and serum albumin concentration, the two recognized markers of malnutrition. It is possible to prevent malnutrition if the circumstances likely leading to poor eating are recognized. Foods soft enough to be easily chewed and swallowed are necessary for the patients in such cases. The ideal consistence of the foods is thick porridge made with the same ingredients as the rest of family, but in purred form.

Scientific evidence has accumulated significantly in the last two decades regarding the beneficial role of unsaturated fatty acids present in beans, nuts, and grain (Hu and Willett, 2002). Beans, regardless of form, are a low fat alternative to animal proteins due to their rich nutrient content. Soybeans are now recognized as a good source of protein with essential amino acids and moderate amounts of unsaturated fatty acid. Studies on the effects of small amounts of isoflavones in soybeans given to animals suggest a favorable antioxidant effect (lipoprotein oxidation) and cholesterol reduction (Sack et al., 1994; Kanazawa et al., 1995; Hodgson et al., 1996). Similarly, pigmented/colored beans (e.g., red kidney, black, pinto) are good sources of antioxidants and are comprised mainly of the soluble form that helps lower blood cholesterol, a main risk factor for the development of cardiovascular disease (Wu et al., 2004; Granito et al., 2008). Nuts are complex food matrices containing diverse nutrients, minerals, antioxidants, and other phytochemicals that may favorably influence human physiology. The fatty acid composition of nuts is beneficial, because the saturated fatty acid (SFA) content is low (4–16%). Furthermore, almost one-half of the total fat content of most nuts is made up of unsaturated fatty acids, monounsaturated fatty acid (MUFA, oleic acid). A predominance of polyunsaturated fatty

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acid (PUFA, linoleic acid) over MUFA is found in pine nuts, and PUFA, both linoleic and α-linolenic acids (C18:3n-3; ALA), are found in walnuts (Ros and Mataix, 2006). The proportion of linoleic acid to ALA in walnuts is about 4:1. At the cellular level, these two fatty acids are substrates for the same desaturation and elongation enzymes in the biosynthetic pathway, leading to eicosanoid production (Calder, 2004). Walnut intake may contribute to a good ratio of linoleic acid to ALA by beneficially influencing eicosanoid production (Wijendran and Hayes, 2004). Increased consumption of whole grains has been associated with a reduced risk of developing major chronic diseases. These health benefits have been attributed in part to the unique phytochemicals, including carotenoids, vitamin E, and phenolics found in whole grains, resulting in potent free radical-scavenging ability (Liu, 2004; 2007). Rice bran contains high amounts of fiber and bioactive phytochemicals, recognized as bioactive compounds improving vital functions including radical scavenging ability, enhancement of immune systems, and the reduction of cancer and heart disease risks (Xu et al., 2001; Okarter et al., 2010). Specifically, black rice is a good source of fiber, minerals, and phytochemicals besides basic nutrients (Zhang et al., 2004). The popularity of black rice is partially due to the distinct compositions of phytochemicals, especially flavonoids and anthocyanins, which have been shown to have beneficial effects in the prevention of chronic diseases associated with oxidative stress (Zhang et al., 2005).

In people who have difficulty chewing foods and maintaining balanced nutrition, the intake of porridge with beans, nuts, and grains not only may help to improve beneficial nutrition, but also prevent the risk of chronic diseases, owing to the effects of radical scavenging ability. Therefore, the present study was set up to explore the possibilities of using various types of beans, nuts, and grains to develop a wide variety of porridges as a value-added instant rice product. The objectives of this study were to develop a nutritious and palatable porridge including various cereals with radical-scavenging ability and compare the differences in radical scavenging ability and textural properties between the rice porridge and cereal-based porridges with additional constituents such as various types of beans, nuts, and grains.

Materials and Methods

Sample preparation and production of porridges based on each formulation. All porridges were made of rice (Hongcheon, Gangwon, Korea) as the main ingredient. Other ingredients, produced in different area in Korea, were bought from a local market. Walnut was imported from California in the Unite State. The porridges were made of rice added with other ingredients at various percentages (Table 1). For general porridge processing, rice or/and bean was soaked in cold water for 1–2 h. Nut and water were mixed in the blender (Electrolux -Le Robot-Coupe, France), and the wet rice and nut were poured into a stainless steel pot (Amicook, Korea), cooked at medium high heat with stirring using a wooden spoon. After the porridge thickened, it was cooled in a refrigerator for 6 h and stored at 4^{o}C until analysis for less than 2 weeks.

Textural profile analysis of porridges. Textural properties of the porridges were determined using a TA-XT2 texture analyzer (TMS-Pro, Food Technology Co., USA). Texture parameters such as hardness, adhesiveness, cohesiveness, springiness, and gumminess were measured in triplicate. The following instrumental test parameters were used: mode was force in compression; load cell value 25 N; trigger type was auto 0.1 N; and a flat cylindrical probe (20 mm diameter) was used (Table 2). Aliquot of each porridge was poured into three sample beakers and immediately put in the water bath maintained at 60^{o}C for 20 min. The beakers were covered with aluminum foil. To determine the texture of the porridges, the aluminum foil was removed from the beaker, and the surface layer of each porridge was scraped off. The beaker was then firmly secured centrally on the texture analyzer stage. The test cycle was started immediately, and the force-time curve was recorded.

Consumer sensory evaluation of porridges. For the consumer

Table 1 Ingredient percentage of different porridges

Ingredients	Formulation (%)					
	plain	Black rice	Bean	Walnut (pine nut)	Wild sesame	mixed grains
Rice	16	11	6	11	6	6
Bean (black,white)	-	-	15	-	-	-
Nut (pine nut, walnut)	-	-	-	5	-	-
glutinous rice	-	-	6	-	6	-
Black rice	-	5	-	-	-	4
Brown rice	-	-	-	-	-	4
Millet	-	-	-	-	-	4
African millet	-	-	-	-	-	4
Wild sesame	-	-	-	-	4	-
Water	84	84	73	84	84	78
Total	100	100	100	100	100	100

Table 2 Measurement condition for texture analyzer

Measurement	Condition
Table speed (mm/min)	50 mm/min
Trigger (N)	0.1 N
Entry depth (mm)	10 mm
Sample height (mm)	50 mm
Adaptor	Ø20 mm
Load cell (N)	25 N

sensory evaluation, an aliquot amount (200 g) of each porridge sample was heated in a microwave for 5 min and then a single serving of each porridge was transferred into 3-digit-coded small cups and served to panelists in private booths. Thirty-five volunteers participated in the randomized incomplete block design sensory evaluation panel. Eight selected porridges were served to the panelists in a single session (block). The porridge samples were prepared the morning of sensory evaluation. All evaluations were conducted at room temperature (24±1°C) on the same day. Each porridge sample was presented in random order, and panelists were asked to rate their preference with regards to color, texture, flavor, and overall acceptability on a nine-point hedonic scale as described by Meilgaard et al. (1999). The nine structural levels ranged from 9, 'like extremely', through 5, 'neither like nor dislike', to 1, 'dislike extremely'. Questions and scales were displayed on the given paper, and responses of panelists were entered manually in the paper for analysis. The panelists were also given an opportunity to write individual comments describing the sensory characteristics of the different porridges.

Determination of antioxidant capacity of porridges by the 1-diphenyl-2-picrylhydrazyl DPPH method. The DPPH method reported by Shim (2012) was carried out to determine the radical scavenging ability of individual porridges with slight modifications. A weighed portion (20 g) of homogenized porridge was mixed with 100 mL of 90% methanol and heated at 50°C in a shaking water bath (Hanbaek Scientific Co., Korea) for 2 h. The extracts, each done in triplicate, were then filtered with a 0.45-μm filter. An aliquot amount μL of 1-diphenyl-2-picrylhydrazyl (DPPH) solution was added into extract and then left for 30 min in a dark place. Absorbance was measured at 517 nm using multi-microplate reader (Varioskan Flash, Thermo Fisher Scientific, Finland). Ascorbic acid was used for positive control. Antioxidant capacity was calculated as follows:

$$\text{Antioxidant capacity (\%)} = 100 - [100*(\text{sample-blank})\text{abs}/(\text{control-blank})\text{abs}]$$

Statistical analysis. All data were analyzed using SAS software, version 9.1 (SAS institute, Inc., USA). Total phenolic acid (TPA) measurements and analyses of radical scavenging ability were conducted in triplicate. Analysis of variance (ANOVA) was performed on a 5% level of significance. Relationships between texture parameter analysis and sensory attributes were determined using Pearson's correlation coefficients.

Results and Discussion

Texture profile analysis (TPA). Table 3 shows the mean values with standard deviation for TPA of porridges. Hardness of porridges mixed with different types of beans, nuts or grains was significantly lower than that of plain rice porridge (0.547) ($p <$ 0.05). The hardness of porridges with added beans, grains, and nuts varied from 0.181 to 0.260, from 0.172 to 0.343, and from 0.232 to 0.310, respectively. Among porridges, white bean and mixed five grains had the lowest hardness at 0.181 and 0.172, respectively. Decreases in the hardness of porridges with added various beans, grains, and nuts may be attributed to the released water from added ingredients during cooking, providing moisture and making them less hard than plain rice porridges. Mixed grains porridges had significantly lower values for hardness and chewiness. Decreases of hardness in porridges including beans, nuts, and grains compared to plain rice porridge may help ease chewing for those with difficulty in masticating foods. The cohesiveness of porridges prepared with beans, sesame, black rice, mixed grains, and walnut porridges ranged from 0.507 to 0.713, which is approximately 1 to 1.5 times higher than that of plain rice porridge (0.43), whereas pine nut porridge (0.407) showed similar a value of cohesiveness to plain rice porridge. Cohesiveness indicates the degree to which a particular sample is likely to hold its texture after compression. The addition of beans, grains, and nuts into porridge may be responsible in increasing the cohesiveness of the porridges by allowing porridges to retain their shape after compression. The springiness of porridges was increased on a parallel pattern with cohesiveness. The average springiness of

Table 3 Instrumental value for TPA curve parameters observed for porridges

	Plain rice	White bean	Black bean	Black rice	Wild sesame	mixed grains	Pine-nut	Walnut
Hardness	0.54±0.02[a)]	0.18±0.01	0.26±0.02	0.30±0.00	0.34±0.01	0.17±0.02	0.31±0.05	0.23±0.01
Adhesiveness	1.34±0.02	0.54±0.02	1.03±0.07	0.47±0.26	1.27±0.04	0.23±0.05	0.103±0.07	0.72±0.02
Cohesiveness	0.43±0.05	0.71±0.01	0.66±0.01	0.50±0.04	0.64±0.01	0.52±0.02	0.40±0.04	0.63±0.01
Springiness	7.50±0.60	9.65±0.22	9.54±0.31	8.93±0.46	9.47±0.39	9.55±0.11	9.04±0.59	9.28±0.10
Gumminess	0.23±0.03	0.13±0.01	0.17±0.01	0.15±0.01	0.22±0.01	0.09±0.01	0.12±0.01	0.14±0.01
Chewiness	1.78±0.33	1.24±0.11	1.64±0.16	1.37±0.21	2.09±0.15	0.86±0.05	1.11±0.08	1.36±0.10

[a)]Mean values with standard deviations (n =3), different letters within a row differ significantly (p <0.05)

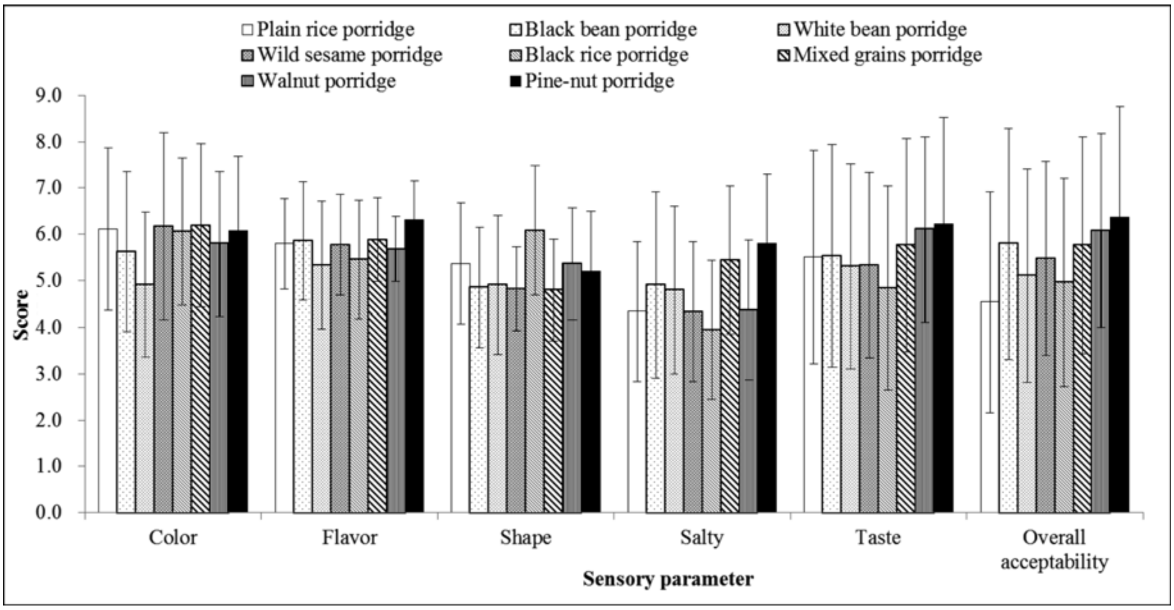

Fig. 1 Consumer panel sensory scores of porridges: 1= dislike extremely (not salty), 5= neither like nor dislike, 9= like extremely (extremely salty). *Sensory analysis was performed by 35 untrained panelists.

porridges made with beans (9.547–9.653), grains (8.937–9.553), and nuts (9.040–9.283) was higher compared to plain rice porridges (7.50). For a similar reason, the moisture content released from added ingredients while cooking porridges can increase the springiness. Gujral and Kumar (2003) reported that the primary factor increasing cohesiveness and springiness of cooked rice is moisture content (Gujral and Kumar, 2003). Chewiness, determined as a mathematical product of hardness, cohesiveness, and springiness, was also measured. Chewiness of black soy bean porridges was not significantly different from plain rice porridges, whereas sesame porridges showed a higher value of chewiness than plain rice porridges. The adhesiveness was decreased by 92.3, 82.8, 64.4, and 59.5% in pine nuts porridge, mixed grains porridge, black rice porridge, and white bean porridges, respectively, indicating that these porridges are less sticky compared to plain rice porridges. Gumminess is the extent to which porridge tends to be sticky, and is relevant to adhesiveness. Gumminess of various types of porridges showed a similar pattern to adhesiveness. The value of gumminess was lower in various types of porridges than plain rice porridge. However, the gumminess of wild sesame porridge (0.220) was comparable to that of plain rice porridge (0.223). Because of the amylopectin content, differences in gumminess may be responsible for the physical-chemical characteristics (gel or viscosity) of porridges. Previous studies reported significant differences in gumminess among porridges depend on the starch content (Lee et al., 2002; Yang et al., 2007).

Sensory evaluation of porridges. Sensory evaluations for a variety of porridges were performed by consumer panels. Fig. 1 shows the individual sensory parameters including color, flavor, shape, salty, taste, and overall acceptability by scoring on a hedonic scale of 0–9, from poor to excellent. To measure discrimination among porridges, a one-way analysis of variance was used. Overall, there was no statistical difference in any of sensory attributes among porridges due to individual panelist variation. This implies that consumers tend to have more difficulty in rating sensory intensity attributes. There was a wide range in ratings for overall acceptability (4.54 to 6.37) and saltiness (3.90 to 5.80), but smaller difference in ratings for flavor (5.34 to 6.31) (Table 4). When compared to plain rice porridges, the average ratings for color, flavor, and shape of black bean and white bean porridges were lower. This indicated that porridges prepared with white and black beans appeared to be unfavorable to consumers. White bean porridges scored lower than 5, a score considered as the limit of acceptability, in color and shape attributes evaluated. Pine-nut and mixed porridges had the highest scores for saltiness but was within the acceptable range. For the ratings of taste and overall acceptability, black rice, walnut, and pine-nut porridges showed higher values than plain rice porridges. The highest correlation was found between overall acceptability and taste ($r = 0.768$), whereas the least relationship was shown with shape ($r = -0.331$) (data not presented).

Correlations between sensory attributes and instrumental parameters. The correlation coefficient between consumer sensory score and instrumental TPA value is presented in Table 5. Consumer sensory attributes of springiness were highly correlated with instrumental springiness ($r = +0.731$, $p < 0.05$) and cohesiveness ($r = +0.639$, $p < 0.05$).

Springiness is defined as the degree or rate at which the sample returns to its original size/shape after partial compression between the tongue and palate. Cohesiveness is defined as the amount of

Table 4 Consumer sensory values on texture of porridges

	Adhesiveness	Springiness	Softness	Viscosity
Plain rice porridge	5.743±1.336[a)]	5.743±1.771	5.286±1.126	5.514±1.269
Black bean porridge	5.229±1.416	5.000±1.663	5.057±1.211	5.171±1.043
White bean porridge	5.486±1.704	4.657±1.697	4.943±1.392	5.743±1.578
Wild sesame porridge	5.343±1.327	5.086±1.222	4.771±1.239	4.971±1.043
Black rice porridge	5.229±1.330	5.429±1.290	5.800±1.324	5.714±1.319
Mixed grains porridge	5.943±1.626	5.314±1.778	4.771±1.031	5.257±0.886
Pine-nut porridge	5.686±1.430	5.286±1.582	5.029±1.445	5.114±0.796
Walnut porridge	5.714±1.363	5.571±1.558	5.257±1.146	5.686±1.132

[a)]Mean values with standard deviations (number of panelist =35), different letters within a column differ significantly (p <0.05)

Table 5 Pearson's correlation coefficients between consumer sensory evaluation and instrumental parameters

Consumer sensory value	TPA value						
	Adhesiveness	Gumminess	Springiness	Chewiness	Hardness	Viscosity	Cohesiveness
Adhesiveness	-0.328	-0.350	-0.610	-0.533	-0.008	-0.244	-0.399
Springiness	0.134	0.259	0.731*	0.044	0.582	0.350	0.639*
Softness	-0.013	0.138	-0.458	0.032	0.303	0.442	-0.286
Viscosity	-0.128	-0.164	-0.202	-0.264	-0.100	0.067	0.163

*Correlation coefficients reported were only those with statistical significance (i.e. p <0.05)

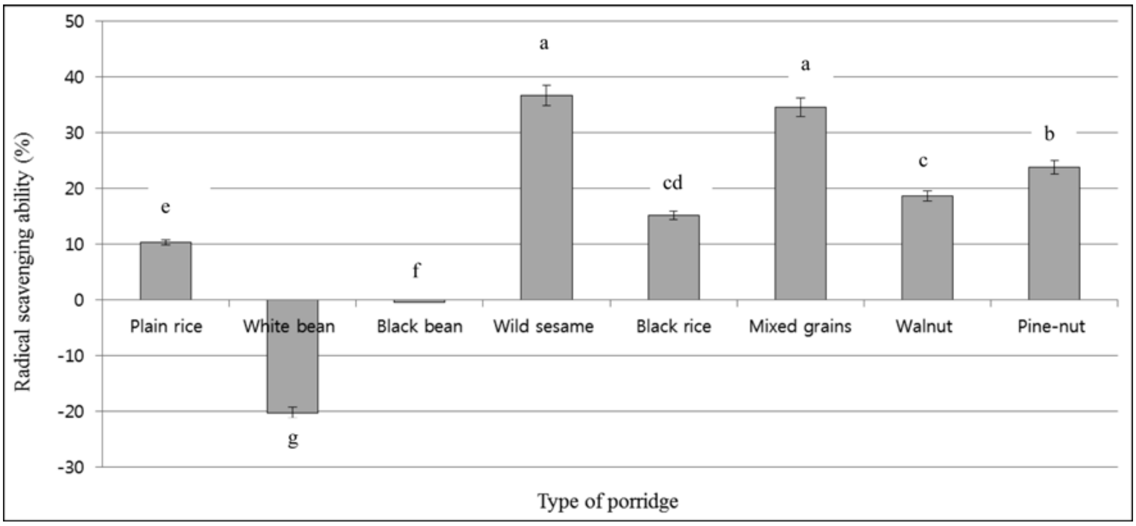

Fig. 2 Radical-scavenging ability of porridge using the DPPH method. ** Different letters above bar are significantly different by Duncan's multiple range tests at p <0.05 after determination by ANOVA.

deformation undergone by a material before rupture when biting completely through the samples using molars. No significant correlations were found between sensory and instrumental TPA parameters for other parameters. Meullenet et al. (1998) suggested that transformed mean values using logarithmic transformations increased correlations between sensory attributes and their instrumental outcomes in many food products. However, porridges in the present study had no correlations between sensory evaluation and TPA using logarithmic transformations.

Difference in radical-scavenging abilities among porridges. The radical-scavenging abilities of the different types of porridges were measured using the DPPH method (Fig. 2). The radical-scavenging abilities of porridges added with pine-nuts and walnuts were higher than those of plain rice porridges. Similarly, grain porridges such as wild sesame, black rice, and mixed grains had 2–4 times higher radical-scavenging ability than plain rice porridges.

The antioxidant activity seemed to be affected by content of unsaturated fatty acids and vitamin E, because vitamin C equivalent (μg/mL) was not relevant to antioxidant activity (data not shown). Therefore, further assays should be conducted to measure antioxidant capacity using different ingredients in porridges.

Nuts are well-documented in human studies to be good sources of omega-3 fatty acids, which are good for prevention of cardiovascular disease and improve brain development. In contrast to nuts and grains, white and black beans showed negative values for radical-scavenging ability. Previous study reported that radical-scavenging ability of whole grain cereals is higher than that of refined grain cereals due to bran and germ being intact. Kidney beans and pinto beans were by far the best source of phenol antioxidants, as measured in terms of fresh weight. This can be ascribed to the high phenol concentration of beans and <10% water by weight (Vinson et al., 1998).

Considering the recent consumer demand for healthy foods and related products, the use of a variety of beans, grains, and nuts, which provide higher nutritional values than plain rice porridge, is a promising alternative. Results of the present study suggested that various types of porridges with beans, grains, and nuts outweigh plain rice porridge in not only textural and sensory characteristics, but also biological activity such as antioxidative effect. Various ingredients for preparing porridges used in the present study produced desirable physical properties and acceptable sensory quality, with added health value. Different types of beans, grains, and nuts could be promising products or ingredient for porridges.

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