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Research Note

Classification of 31 Korean Wheat (*Triticum aestivum* L.) Cultivars Based on the Chemical Compositions

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ABSTRACT: Whole grain wheat flour (WGWF) is the entire grain (bran, endosperm, and germ) milled to make flour. The WGWF of 31 Korean wheat (*Triticum aestivum* L.) cultivars were analyzed for the chemical compositions, and classified into groups by hierarchical cluster analysis (HCL). The average composition values showed a substantial variation among wheat varieties due to different wheat varieties. Wheat cv. Shinmichal1 (waxy wheat) had the highest ash, lipid, and total dietary fiber contents of 1.76, 3.14, and 15.49 g/100 g, respectively. Using HCL efficiently classified wheat cultivars into 7 clusters. Namhae, Sukang, Gobun, and Joeun contained higher protein values (12.88%) and dietary fiber (13.74 %). Regarding multi-trait crop breeding, the variation in chemical compositions found between the clusters might be attributed to wheat genotypes, which was an important factor in accumulating those chemicals in wheat grains. Thus, once wheat cultivars with agronomic characteristics were identified, those properties might be included in the breeding process to develop a new variety of wheat with the trait.

Keywords: wheat cultivar, whole wheat meal, chemical composition, cluster analysis

INTRODUCTION

Whole wheat flour contains more vitamins, minerals, antioxidants, and other nutrients than regular wheat flour because those compounds are concentrated in the outer portions of the wheat grain. The two outer parts of the grain, the bran and germ, contain most of the dietary fiber and other bioactive components (1). From numerous researches, it is widely accepted that dietary fiber is associated with the prevention of diseases and beneficial to human health. The beneficial effects of high dietary fiber intake include the protection against heart disease and cancer, regulation of glucose absorption and insulin secretion, and prevention of intestinal disease (2,3). Regarding the reduction of colorectal cancer, studies reported that intake of total dietary fiber of 10.0 g/d reduced the risk of colorectal cancer by 10%. Based on research findings, researchers recommend 30 g of dietary fiber consumption daily (4).

Wheat consumption from a variety of foods is increasing in Korea, as it is an important source of daily foods. Most of the wheat products, like white bread, noodle, and cookies, are produced from white wheat flour in which most nutritional components are removed during the milling process (5). Slavin et al. (6) reported that the dietary fiber content of whole wheat flour and white flour is approximately 12.1% and 2.8%, respectively. Gebruers et al. (7) observed the phytochemical and dietary fiber contents of 151 wheat cultivars, and found that dietary fiber content varied among species and varieties from the lowest levels of 7.2～12.0% to the highest of 11.5～18.3%.

Whole wheat flour has higher health benefits compared to wheat flour, but the consumption of whole wheat products is estimated to be too low. This is probably a less favorable end-use property of whole wheat products due to the bran and germ, which deteriorate rheological characteristics. Thus, the inferior quality of whole grain products has been an issue, and research has been focused on enhancing the nutritional and functional quality of the final products from whole wheat flour (8). The goal of this study was to evaluate the compositions, emphasizing on the dietary fiber and protein contents, of 31 Korean wheat cultivars and to categorize them into groups with a high similarity in the chemical compositions in order to specify a potential genetic source for wheat breeding lines with high dietary fiber content.

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MATERIALS AND METHODS

Materials

Thirty-one Korean wheat cultivars were developed and grown in the research field of the National Institute of Crop Science, RDA, in the 2012～2013 crop seasons. The wheat grain was ground using a hammer mill (Laboratory Mill 3100, Pertent Co., Ltd., Huddinge, Sweden) equipped with a 0.5 mm screen to prepare whole grain wheat flour (WGWF). The WGWF was stored at 4°C for the chemical composition analysis.

Compositional analysis

Ash contents were determined according to the American Association of Cereal Chemists official method (9). Crude protein contents were measured by analyzing total nitrogen contents using an elemental analysis (Perkinelmer 2410, Elemental Analyzer System, Vario MACRO, Jena, Germany). Crude lipid content was analyzed by the Soxhlet extraction method with absolute ethyl ether as a solvent using a Soxtec 2050 (Foss Tecator, Eden Prairie, MN, USA).

Total dietary fiber (TDF) contents were determined according to the AOAC official method (10), an enzymatic-gravimetric method with the buffer solution of 4-morpholineethanesulfonic acid (MES) and 2-amino-2-(hydroxymethyl)-1,3-propanediol (TRIZMA). Whole wheat meal (1.0 g) was suspended in MES-TRIZMA buffer and digested sequentially with heat-stable α-amylase, protease, and amyloglucosidase for further starch and maltodextrin hydrolysis. The digested mixture was precipitated with 95% ethanol followed by filtering with ethanol, and the filtered residues were dried until a constant weight was achieved. Analysis was conducted using dietary fiber extraction equipment (Fibertec^{TM} System, 10223 Filtration Mdule, Foss Tecator). Carbohydrate content was determined by the difference. Chemical composition determination was conducted in triplicates.

Statistical analysis

Data was analyzed using SAS statistical software (Version 9.1, SAS Institute Inc., Cary, NC, USA). Hierarchical cluster analysis (HCA) based on squared Euclidean distance and ward's method were applied to categorize the wheat cultivar. The number of clusters was determined by considering the root-mean-square standard deviation (RMSSTD) values.

RESULTS AND DISCUSSION

Table 1 summarizes the average values of ash, crude lipid, crude protein, TDF, and carbohydrates in WGWF of 31 Korean wheat cultivars. Wheat types included hard, all-purpose (medium), and soft wheat, which are categorized by the end-use purposes based on protein contents: proteins of 13～14% for hard wheat, 10～11% for all-purpose wheat, and 8～9% for soft wheat. Wheat cultivars contained 4 hard wheat, 20 all-purpose wheat, and 7 soft wheat cultivars. The mean values for the chemical compositions of wheat cultivar varied due to different wheat varieties.

Approximate compositions of ash, lipid, and protein contents of WGWF ranged in 0.94～1.75%, 1.44～2.98, and 9.27～13.59%, respectively. Wheat cv. Shinmichal1, which is a waxy red wheat for all-purpose uses, had the highest ash, lipid, and TDF contents of 1.76, 3.14, and 15.49 g/100 g, respectively. The lowest TDF content of 10.68 g/100 g was shown in "Keumkang", which is a hard white wheat. Protein content is the critical value for the final uses of wheat flour such as bread (hard wheat), noodle (all-purpose wheat), and cookie (soft wheat). Wheat cultivars Keumkang, Dajung, Joeun, and Sukang contained high protein contents of 13.06～13.59 g/100 g. Whereas wheat cultivars Milseoung, Dahong, Jinpum, Shinmichal1, and Baekjoong contained low protein contents of 9.72～10.95 g/100 g. The TDF content varied by wheat cultivars and ranged between 11.20 g/100 g and 15.49 g/100 g.

Gebruers et al. (7) examined the phytochemical and dietary fiber contents of wheat cultivars, which included 151 common winter and spring wheat varieties, 10 durum wheat varieties, and 15 other wheat varieties, such as spelt, einkorn, and emmer wheat. They found that the TDF contents of whole grain samples varied among varieties, reporting that common wheat had the highest TDF content (11.5～18.3%), whereas einkorn and emmer wheat had the lowest TDF content (7.2～12.8%). Regarding the large variation on TDF content, they concluded that different wheat types and varieties substantially resulted in the large variation in TDF content. Graybosch (11) studied the applications of waxy wheat flour, and suggested the waxy wheat flour as blending wheat to develop flours with specific amylose contents.

The 31 Korean wheat cultivars were categorized into groups using a HCA with respect to chemical compositions. HCA is a multivariate analysis that classifies groups of individuals or objects that are similar to each other but different from individuals in other groups. Wheat cultivars were grouped into 7 clusters, shown in Table 2. The first cluster grouped 3 wheat cultivars, Baekjoon, Jeokjoong, and Jinpum. The second group contains 9 wheat cultivars Alchan, Tapdong, Anbaek, Jopum, Suan, Ol, Younbaek, Seodun, and Dabun. The third group has 7 wheat cultivars Olgeuru, Saeol, Jokyung, Goso, Keumkang, Dajung, and Geuru. Wheat cultivars for the other four groups are Nahae, Sukang, Gobun, and Joeun for the fourth cluster, Hanbaek, Uri, and

Table 1. Chemical compositions of whole grain wheat flour (WGWF) from 31 Korean wheat cultivars

Cultivar	Compositions (%)					Wheat type
	Ash	Lipid	Protein	TDF[1)]	Carbohydrates	
Jopum	1.57±0.08	2.17±0.05	11.59±0.12	13.25±0.39	71.41±0.39	Hard red wheat
Milseoung	1.20±0.15	2.14±0.00	10.95±0.10	11.82±0.69	73.89±0.94	Hard red wheat
Jokyung	1.35±0.17	2.54±0.00	11.82±0.04	12.54±0.05	71.75±0.26	Hard white wheat
Keumkang	1.42±0.04	2.08±0.01	13.59±0.06	11.33±0.28	71.58±0.37	Hard white wheat
Anbaek	1.66±0.05	2.12±0.08	11.35±0.13	12.93±0.60	71.94±0.44	Red wheat
Chungkye	0.94±0.07	2.05±0.02	11.61±0.00	13.15±1.13	72.25±1.03	Red wheat
Dabun	1.57±0.05	2.44±0.06	11.07±0.04	12.82±0.16	72.09±0.32	Red wheat
Dahong	1.23±0.08	2.53±0.04	9.95±0.04	12.63±0.33	73.66±0.51	Red wheat
Dajung	1.49±0.02	2.34±0.17	13.06±0.08	11.22±1.52	71.88±1.42	Red wheat
Eunpa	1.50±0.01	1.44±0.01	11.41±0.01	13.67±0.24	71.97±0.28	Red wheat
Geuru	1.54±0.09	2.94±0.06	12.26±0.09	11.72±0.41	71.54±0.35	Red wheat
Jeokjoong	1.66±0.03	2.16±0.05	9.27±0.09	12.29±0.02	74.60±0.01	Red wheat
Jinpum	1.41±0.09	1.73±0.18	10.49±0.04	11.46±0.02	74.91±0.25	Red wheat
Joeun	1.53±0.09	1.92±0.04	13.49±0.01	13.39±0.34	69.66±0.31	Red wheat
Jonong	1.27±0.01	2.18±0.01	12.26±0.02	13.76±0.03	70.53±0.05	Red wheat
Namhae	1.61±0.06	2.44±0.09	12.72±0.14	14.42±0.74	68.82±0.72	Red wheat
Ol	1.73±0.02	2.19±0.03	11.69±0.04	11.20±0.84	73.18±0.89	Red wheat
Saeol	1.34±0.03	2.40±0.12	11.62±0.12	12.21±0.62	72.43±0.83	Red wheat
Suan	1.68±0.02	1.89±0.16	11.06±0.03	13.23±0.18	72.13±0.39	Red wheat
Sukang	1.69±0.04	2.27±0.04	13.15±0.02	13.71±0.06	69.19±0.13	Red wheat
Tapdong	1.62±0.00	1.91±0.01	11.15±0.02	13.72±0.82	71.60±0.83	Red wheat
Shinmichal1	1.66±0.01	2.98±0.18	12.00±0.09	15.49±0.54	67.87±0.30	Red waxy wheat
Hanbaek	1.48±0.05	1.72±0.02	11.22±0.01	12.96±0.06	72.63±0.02	White wheat
Younbaek	1.75±0.09	2.23±0.02	11.43±0.06	11.95±0.19	72.64±0.03	White wheat
Alchan	1.57±0.04	2.03±0.04	11.02±0.01	13.45±0.63	71.93±0.62	Soft red wheat
Gobun	1.72±0.04	2.12±0.11	12.16±0.05	13.42±0.11	70.58±0.31	Soft red wheat
Goso	1.37±0.08	2.17±0.02	12.76±0.12	11.78±1.86	71.91±1.63	Soft red wheat
Olgeru	1.33±0.01	2.22±0.00	11.98±0.02	12.26±0.25	72.21±0.26	Soft red wheat
Seodun	1.50±0.00	2.05±0.08	11.47±0.08	12.72±0.31	72.25±0.16	Soft red wheat
Uri	1.43±0.09	1.62±0.00	11.43±0.08	12.05±0.11	73.47±0.12	Soft red wheat
Baekjoong	1.69±0.05	2.15±0.08	9.72±0.06	12.28±0.19	74.15±0.25	Soft white wheat

[1)]Total dietary fiber.

Table 2. Classification of 31 Korean wheat cultivars by cluster analysis

Clusters	Wheat cultivars
1	Baekjoong, Jeokjoong, Jinpum
2	Alchan, Tapdong, Anbaek, Jopum, Suan, Ol, Younbaek, Seodun, Dabun
3	Olgeuru, Saeol, Jokyung, Goso, Keumkang, Dajung, Geuru
4	Namhae, Sukang, Gobun, Joeun
5	Hanbaek, Uri, Eunpa
6	Dahong, Milseoung, Chungkye, Jonong
7	Shinmichal1

Eunpa for the fifth cluster, Dahong, Milseoung, Chungkye, and Jonong for the sixth cluster, and Shinmichal1 for the seventh cluster. The cluster can be identified in the dendrogram from the HCA results by Ward's clustering analysis in Fig. 1. The HCA application to the wheat cultivar resulted in the identification of 7 distinctive groups with respect to chemical contents in wheat cultivar.

Table 3 shows the mean values of 5 compositions of wheat cultivars grouped in 7 clusters. The seventh cluster contains only one cultivar "Shinmichal1", which is a waxy wheat variety, and it shows the highest values for ash (1.66%), lipid (2.98%), and TDF (15.49%) with the lowest carbohydrates (67.87%) content. The fourth cluster shows the average values of protein (12.88%) and TDF (13.74%) with low carbohydrates (69.56%) content, and the highest protein content. The first group contained the lowest protein content of 9.83 g/100 g. Regarding multi-trait crop breeding, variation in chemical compositions found between clusters might be attributed to wheat genotypes, which were important factors on accumulating those chemicals in wheat grains. A large variation in grain traits has been reported as the variation in compositions due to specific genotypes and cultivation environment conditions. Hussain et al. (12) observed the mineral content of wheat grain, and they emphasized that the specific genotype was the most important factor to consider for the production of wheat with high miner-

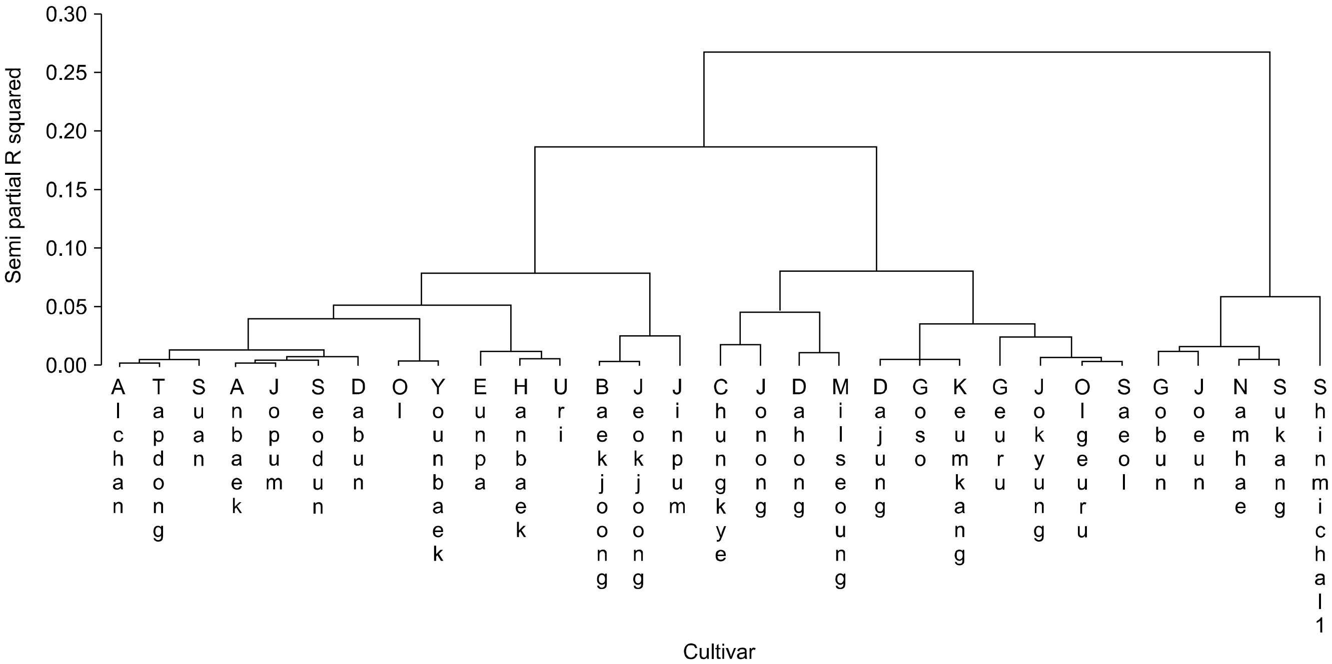

Fig. 1. Dendrogram based on hierarchical clustering analysis (HCA) for the chemical compositions of 31 Korean wheat cultivars.

Table 3. Cluster mean values of 31 Korean wheat cultivar clustered into 8 groups

Cluster	Ash	Lipid	Protein	TDF[1)]	Carbohydrates
1	1.59±0.15	2.02±0.24	9.83±0.61	12.01±0.48	74.56±0.38
2	1.63±0.08	2.12±0.19	11.31±0.25	12.81±0.79	72.13±0.53
3	1.41±0.08	2.38±0.29	12.44±0.72	11.87±0.49	71.90±0.32
4	1.64±0.09	2.19±0.22	12.88±0.58	13.74±0.48	69.56±0.76
5	1.47±0.04	1.59±0.14	11.35±0.12	12.89±0.81	72.69±0.75
6	1.16±0.15	2.22±0.21	11.19±0.98	12.84±0.82	72.58±1.55
7	1.66±0.00	2.98±0.00	12.00±0.00	15.49±0.00	67.87±0.00

[1)]Total dietary fiber.

al content. In addition, as part of the HEALTHGRAIN diversity screening program, which explored the extent variation in phytochemicals and other bioactive components in the gene pool available for plant breeders, they concluded that the diversity of those components was found in not only different types of wheat but also rye (13), barley (14), and oats (15). The chemical composition analysis for 31 Korean wheat cultivars showed apparent differences in their contents due to the chemical characteristics of various wheat varieties. Wheat cv. Shinmichal1, a waxy wheat cultivar, contained the highest chemical compositions of ash, lipid, and TDF. The application of HCA was efficient in classifying wheat cultivars based on the chemical compositions, resulting in 7 clusters. Among the groups, the fourth cluster included wheat varieties with higher functional compositions, for protein and dietary fiber contents beside of the seventh cluster containing one wheat cv. Shinmichal1. Once wheat cultivars with interested agronomic characteristics are identified, they could be included in the breeding process to develop a new variety of wheat.

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AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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