

Mineral Compositions of Korean Wheat Cultivars

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ABSTRACT: Twenty-nine Korean wheat cultivars were analyzed for 8 important minerals (Cu, Fe, Mn, Zn, Ca, K, Mg and P) using Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES). A hierarchical cluster analysis (HCA) was applied to classify wheat cultivars, which has a similarity in mineral compositions. The concentration ranges of the micro-minerals Cu, Fe, Mn, and Zn: 0.12~0.71 mg/100 g, 2.89~5.89 mg/100 g, 1.65~4.48 mg/100 g, and 2.58~6.68 mg/100 g, respectively. The content ranges of the macro-minerals Ca, K, Mg and P: 31.3~46.3 mg/100 g, 288.2~383.3 mg/100 g, 113.6~168.6 mg/100 g, and 286.2~416.5 mg/100 g, respectively. The HCA grouped 6 clusters from all wheat samples and a significant variance was observed in the mineral composition of each group. Among the 6 clusters, the second group was high in Fe and Ca, whereas the fourth group had high Cu, Mn and K concentrations; the fifth cluster was high in Zn, Mg and P. The variation in mineral compositions in Korean wheat cultivars can be used in the wheat breeding program to develop a new wheat cultivar with high mineral content, thus to improve the nutritional profile of wheat grains.

Keywords: Korean wheat, cultivars, minerals, ICP, cluster analysis

INTRODUCTION

Wheat consumption in a variety of food products is continuously increasing in Korea and wheat is considered an important source for daily foods. Wheat products provide mainly carbohydrates, proteins and some essential nutrients required for humans. Minerals are those essential elements that activate enzymes performing metabolic functions of human body process, thus deficiency of certain minerals may develop various chronic diseases (1). Minerals are divided into 2 groups: 1) macronutrients (Ca, Mg, K, P, and S), which are needed in large amounts, and 2) micronutrients (Cu, Fe, Mn, and Zn), referred to trace elements that are needed in small amounts. Studies observed that mineral compositions of wheat are influenced by the factors of genotype and environment. In addition, mineral bioavailability could be increased by selection of wheat cultivars with a higher concentration of minerals, as well as fortification of minerals for wheat products.

Hussain et al. (2) observed the mineral element concentration of 321 winter and spring wheat genotypes selected from multiple locations and years, and report that organic conditions with specific primitive wheat genotypes may enhance mineral contents in wheat grains.

Zhang et al. (3) observed the effects of genotype and environment on mineral elements focusing on Fe and Zn from 24 selected wheat cultivars, reporting a high possibility to combine high Fe and Zn traits in wheat breeding; also, a strong positive correlation between these mineral concentrations and protein content was indicated. On the other hand, the variation of mineral concentration by sprouting wheat grains was observed by Ozturk et al. (4), reporting that mineral contents of two wheat cultivars increased, but decreased in fatty acid with sprouting at 17°C and 85% relative humidity for 9 days.

As wheat becomes one of the most important cereal crops in Asian countries, a demand for wheat grains with high nutritional compositions is also increasing. Therefore, the objective of this study was to observe the mineral element compositions of Korean wheat cultivars, which included 29 wheat cultivars developed and grown in the National Institute of Crop Science in (NICS) Korea.

MATERIALS AND METHODS

Materials

Twenty-nine Korean wheat cultivars developed in the NICS, Rural Development Administration (RDA), were

Received June 20, 2013; Accepted August 23, 2013

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cultivated in the research field of the Department of Rice and Winter Cereal Crop, NICS, in the 2011-2012 crop seasons. Wheat grains were ground using a hammer mill (Laboratory Mill 3100, Pertent Co. Ltd., Huddinge, Sweden) equipped with a 0.5 mm screen to prepare whole wheat flour. The ground whole wheat flour was stored at 4°C for the mineral analysis.

Mineral analysis

Mineral compositions of whole wheat flour were determined by the method of Hwang et al. (5) with slight modifications. One gram of ground whole wheat flour (WWF) was wet-digested in a mixture solution of HNO₃ (10 mL) and H₂SO₄ (10 mL) with heating on a hot plate. After cooling the digested solution, the mixture solution of 2 mL of HCl and 50 mL of distilled water were added and boiled for 30 min. The digested and boiled solutions were filled to 100 mL with distilled water and filtered to obtain the aqueous solution for analysis. Mineral constituents were identified and quantified using an Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES; Varian 730-ES, Varian Inc., Palo Alto, CA, USA).

Statistical analysis

Data was analyzed using SAS statistical software (Version 9.1, SAS Institute Inc., Cary, NC, USA). Hierarchical

cluster analysis (HCA) with 'ward' method was carried out to group the wheat cultivars with similar mineral compositions. The number of clusters was determined by considering the PSF value produced by 'pseudo' analysis.

RESULTS AND DISCUSSION

Eight mineral compositions of 29 Korean wheat cultivars were determined and summarized in Table 1. The observed minerals were micro-minerals of copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn), and macro-minerals of calcium (Ca), potassium (K), magnesium (Mg), and phosphorous (P). The concentration ranges of the micro-minerals Cu, Fe, Mn, and Zn were 0.12~0.71 mg/100 g, 2.89~5.89 mg/100 g, 1.65~4.48 mg/100 g, and 2.58~6.68 mg/100 g, respectively, whereas the ranges for the macro-minerals Ca, K, Mg and P were 31.34~46.34 mg/100 g, 288.22~383.30 mg/100 g, 113.66~168.62 mg/100 g, and 286.22~416.54 mg/100 g, respectively. Wheat cultivars with the highest and lowest micro-mineral elements were 'Jonong' and 'Uri' (0.71 and 0.12 mg/100 g) for Cu, 'Jokyung' and 'Uri' (5.89 and 2.89 mg/100 g) for Fe, 'Hanbaek' and 'Baekjoong' (4.48 and 1.65 mg/100 g) for Mn, and 'Anbaek' and 'Suan' (6.68 and 2.58 mg/100 g) for Zn. For macro-minerals, the

Table 1. Mineral element compositions of 29 Korean wheat cultivars

Cultivars	Mineral compositions (mg/100 g)							
	Cu	Fe	Mn	Zn	Ca	K	Mg	P
Alchan	0.33	3.99	2.60	5.32	46.34	348.54	141.92	406.22
Anbaek	0.32	4.53	2.76	6.68	44.52	336.46	129.38	364.12
Baekjoong	0.51	3.72	1.65	4.85	36.77	351.52	126.50	356.70
Chungkye	0.46	5.21	2.78	6.19	45.75	338.82	132.60	386.94
Dabun	0.53	4.32	2.23	4.42	31.34	339.46	125.10	349.60
Dahong	0.27	4.22	2.33	5.66	44.56	381.02	136.50	405.66
Eunpa	0.30	4.33	2.34	5.62	45.60	332.10	130.78	367.96
Geuru	0.35	3.80	2.22	4.70	39.08	381.96	132.50	375.28
Gobun	0.35	4.41	2.00	6.55	42.28	320.32	146.64	416.54
Hanbaek	0.54	3.85	4.48	5.48	42.26	378.28	152.06	416.00
Jeokjoong	0.52	3.86	3.03	5.26	36.15	371.44	145.00	395.14
Jinpum	0.28	4.35	2.06	5.18	39.55	296.64	119.78	344.60
Joeun	0.38	4.49	2.86	5.78	45.50	339.12	129.28	359.26
Jokyung	0.54	5.89	2.11	4.56	36.29	357.92	125.94	354.68
Jonong	0.71	4.39	3.15	4.90	40.55	327.98	132.32	363.08
Jopum	0.36	4.59	2.31	5.36	38.46	346.02	132.42	363.34
Keumkang	0.39	4.81	2.55	6.36	45.16	296.44	133.72	391.56
Milseoung	0.32	4.56	3.10	5.50	39.67	300.02	134.74	394.00
Namhae	0.30	4.69	2.81	3.70	37.29	373.54	113.66	337.56
Ol	0.36	4.84	2.27	4.97	39.99	351.20	123.70	342.60
Olgeru	0.24	4.07	1.99	4.78	36.60	342.64	126.94	359.26
Saeol	0.30	3.95	2.52	5.04	41.64	288.22	117.06	339.18
Seodun	0.31	4.36	2.65	5.06	37.71	293.36	129.58	364.42
Shinmichal1	0.49	3.26	3.05	4.43	41.65	383.30	149.08	397.94
Suan	0.33	4.75	3.53	2.58	40.96	369.34	118.06	286.22
Sukang	0.61	4.43	3.17	4.71	34.19	341.54	168.62	385.20
Tapdong	0.34	3.87	2.65	4.99	41.20	361.72	126.54	366.06
Uri	0.12	2.89	2.40	3.72	33.21	311.02	116.04	332.68
Younbaek	0.52	3.88	2.94	3.72	38.77	392.20	141.44	373.76

highest and lowest minerals were found in wheat cultivars of 'Alchan' and 'Dabun' (46.34 and 31.34 mg/100 g) for Ca, 'Shinmichal1' and 'Saeol' (383.30 and 288.22 mg/100 g) for K, 'Sukang' and 'Milseoung' (168.62 and 113.66 mg/100 g) for Mg, and 'Gobun' and 'Suan' (416.54 and 286.22 mg/100 g) for P.

A study by Hussain et al. (2) observed mineral compositions of 321 winter and spring wheat genotypes (whole grain) in Sweden. Comparing the mineral element concentration between Sweden and Korean cultivars, the minerals of Fe, Zn, Ca and Mg were slightly higher in Korean cultivars. The mineral composition of wheat flour consumed in Brazil was observed by Araujo et al. (6), reporting that the average values of Ca, Mg, K and P were 27 mg/100 g, 35 mg/100 g, 171 mg/100 g, and 192 mg/100 g, respectively. For micro minerals, the average values of Cu, Fe, Mn and Zn were 0.18 mg/100 g, 3.78 mg/100 g, 0.82 mg/100 g and 0.94 mg/100 g, respectively. On the other hand, Hwang et al. (7) examined the mineral concentrates of rice cultivar 'Josaengheugcha (JSHC)', which is brown rice with reddish-black color. Compared to the results of whole wheat samples, the JSHC contains a lower content of K (221.40 mg/100 g), Mg (92.39 mg/100 g), P (277.30 mg/100 g), and Zn (2.39 mg/100 g), but the JSHC has significantly higher con-

tents of Fe (12.70 mg/100 g) than whole wheat flour.

Numerous studies investigated the important factors on accumulating minerals in the cereal grains. Zhang et al. (3) evaluated the effects of genotype and environment on mineral compositions of wheat grains grown in different locations, and found a large variation for all mineral elements. The report by Hussain et al. (2) clearly showed that wheat cultivar with high concentration of minerals could be produced by the use of specific genotypes in combination with organic cultivation; however, the authors emphasized that the specific genotype can be the most important factor to consider for producing wheat with high mineral concentration. Peterson et al. (8) also reported that the variation in mineral concentration by genotypes was significant and the genotype effect was much larger than environment factors, suggesting that mineral concentration has a high positive correlation with protein content thus achieving nutritional advantage of high-protein cultivars.

In the present study, the 29 Korean wheat cultivars were evaluated and grouped with similarity on real distance using a HCA. By the PSF value produced by 'pseudo' analysis, the wheat cultivars were grouped into 6 clusters, shown as a dendrogram in Fig. 1. The average concentrations of eight mineral elements in each of the 6 clusters are presented in Tables 2 and 3, presenting a variance in the concentration of mineral elements. The first cluster grouped 12 wheat samples of 'Anbaek', 'Joeun', 'Baekjoong', 'Jokyung', 'Jopum', 'Olgeuru', 'Eunpa', 'Jonong', 'Tapdong', 'Dabun', 'Ol' and 'Namhae'. The second group contained the 3 samples of 'Keumkang', 'Milseoung' and 'Seodun' which have the second highest Zn contents (5.64 mg/100 g) followed by the fifth

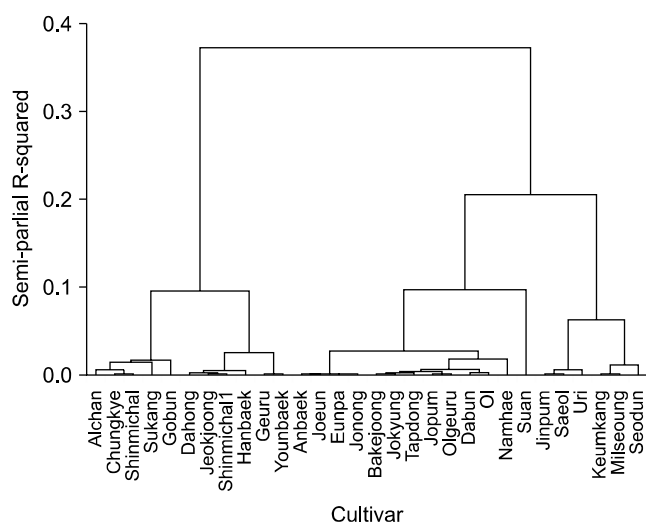


Fig. 1. Dendrogram of 29 Korean wheat cultivars for 8 mineral elements using hierarchical cluster analysis (HCA).

Table 3. Six clusters of 29 Korean wheat cultivars

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

Table 2. The average of 8 mineral elements for each cluster of 29 Korean wheat cultivars

Clusters	Mineral compositions (mg/100 g)							
	Cu	Fe	Mn	Zn	Ca	K	Mg	P
1	0.41±0.14	4.48±0.55	2.43±0.43	5.05±0.75	39.76±4.73	346.64±13.18	126.88±5.02	357.02±9.47
2	0.34±0.04	4.58±0.23	2.77±0.29	5.64±0.66	40.85±3.86	296.61±3.33	132.68±2.73	383.33±16.42
3	0.23±0.09	3.73±0.75	2.33±0.24	4.65±0.81	38.13±4.39	298.63±11.53	117.63±1.93	338.82±5.97
4	0.45±0.11	3.81±0.31	3.01±0.81	4.88±0.73	40.41±2.99	381.37±6.78	142.76±7.45	393.96±16.71
5	0.44±0.13	4.51±0.51	2.64±0.49	5.69±0.83	42.14±5.59	337.31±12.04	147.45±15.27	398.73±15.22
6	0.33	4.75	3.53	2.58	40.96	369.34	118.06	286.22

group. The third cluster has 3 samples of 'Jinpum', 'Saeol' and 'Uri'. On the other hand, the fourth group has 6 wheat cultivars, 'Geuru', 'Younbaek', 'Jeokjoong', 'Shinmichan1', 'Dahong' and 'Hanbaek', high in Cu and K. The fifth group formed 4 wheat cultivars showing high Zn, Mg and P. The sixth group contains only 'Suan' and is characterized with the highest Fe and Mn contents.

Mineral concentration in cereal grains is also influenced by post-harvest treatment, such as wheat milling and processing. A decrease in selenium (Se) during wheat milling dependent on the flour extraction rate caused a variation in mineral concentration (9). On the other hand, Zook et al. (10) observed that most mineral elements were lower in baker's patent flour than in the hard wheat. Mineral contents in cooked and uncooked pasta products were compared by Ranhotra et al. (11), reporting that retention of all minerals after cooking was high except for K; the authors also investigated bioavailability of some mineral elements and found that commercial variety bread ingredients such as wheat bran, soy flour, vegetable flour, which is not purified flour, interfered with the availability of Fe.

Using the HCA was efficient to classify wheat cultivars based on similar mineral compositions, resulting in 6 clusters from the 29 Korean wheat cultivars. Among the 6 groups, the fourth cluster contains 6 wheat cultivars high in Cu and K contents, whereas the fifth group has 4 cultivars with the highest Zn, Mg and P. The sixth cluster with only one wheat cultivar of 'Suan' has the highest Fe and Mn contents. Cereals are staple foods in the world, and wheat is one of the most consumed cereals of human foods. But one problem with eating cereals as a major food is the lack of mineral contents (12). Thus, some countries are suffering mineral deficiency in their daily meal. For this reason, the nutritional evaluation of cereal and its flour is essential to use those cereals efficiently to improve health benefits. In addition, the variation in mineral composition found in the 29 Korean wheat cultivars can be used in the breeding program to develop a new wheat cultivar with high mineral content, thus to improve the nutritional profile of the wheat grains.

ACKNOWLEDGMENTS

The authors acknowledge the financial support for this research from the National Institute of Crop Science (NICS), of the Rural Development Administration (RDA).

AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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