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Contents of Phytic Acid of Various Cereal Crops Produced in Korea

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Abstract - The main objective of the study was to investigate the phytic acid contents of various cereals and legumes produced in Korea. The results showed that the phytic acid contents of buckwheat, foxtail millets, sorghum, millet, barley, jobs' tears, yellow corn and wheat flour (Urimil) were in a range of 0.13 to 2.27%. The contents of the phytic acid ranged from 1.03 to 1.16% for legumes including red Indian bean, black Indian bean, mung bean, and black soybean. The phytic acid content of brown rice was five times higher than those of 100% polished rice. The polishing process of the rice decreased significantly the content of the phytic acid. We estimate that the daily phytic acid intake from rice was changed from 653 mg/day in 1995 to 430 mg/day in 2005 based on the results of a national nutrition survey.

Key words - Cereals, Korean daily intake, Rice, Phytic acid

Introduction

Phytic acid (myoinositol hexaphosphate) is the major phosphorus storage compound discovered in most seeds and various cereal grains. It accounts for more than 70% of the total phosphorus content in seeds (Harlan and Oberleas, 1987; Zhou and Erdman, 1995; Bohn *et al*., 2008).

Phytic acid has been well known to have protective effects against carcinogenesis, beneficial effects in heart disease and other diseases, and also to function as an antioxidant *in vitro*. The mechanism responsible for the desirable effects of phytic acid may be partly related to its antioxidant properties, which allow it to function as an inhibitor of iron-mediated free radical formation (Harlan and Morris, 1995; Zhou and Erdman, 1995).

On the other hand, phytic acid has a strong ability to chelate multivalent metal ions, such as iron, calcium and zinc, resulting in insoluble salts (phytin) with poor bioavailability of minerals (Graf *et al*., 1987; Slavin, 2003; Zhou and Erdman, 1995). This implies that phytic acid may cause mineral deficiency when the consumer has a diet which is marginal in essential minerals.

Phytic acid is typically deposited as discrete globular inclusions in single-membrane storage microbodies. The content of phytic acid is reduced during certain food-processing processes including hulling, milling or grinding (Marfo *et al*., 1990; Liang *et al*., 2008). Thus, the content of phytic acid in cereals may be one of crucial factors to evaluate the nutritional value of the cereals which acts on nutrient or antinutrient (Harlan and Morris, 1995; Zhou and Erdman, 1995).

Nevertheless, only a limited number of findings on the phytic acid content of cereals produced in Korea have been available in the past for national dietary assessment (Lee, 1989; Lee *et al*., 1997; Kim *et al*., 1994; Kim and Kim, 2005). Furthermore, the differences in assay methods reported in the literature do not exclude the possibility of miscalculation during dietary evaluation of phytic acid (Harlan and Oberleas, 1987; Talamond *et al*., 1998).

In this report, we attempted to assess the total phytic content of cereal samples produced and consumed in Korea, and also to estimate the phytic acid intake from the staple food, cereals.

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Materials and Methods

Materials

Each of glutinous white rice and black rice, glutinous foxtail millets (*Setaria italic* Beauv.), unglutinous foxtail millets (*Setaria italic* Beauv.), millet (*Penicum miliaceum* L.), barley (*Hordeum vulgare* L.) buckwheat (*Fagophyrum esculentum* Moench), sorghum (*Sorghum bicolor* Moench), wheat flour (*Triticum* spp. L., Urimil), , Job's tears (*Coix ma-yuen* Roman.), black indian bean (Vigna angularis W.F. Wight), red indian beans (Vigna angularis W.F.Wight), bean, corn (*Zea mays* L.), and mung bean (*Vigna radiate* L.) were purchased from local markets in Gangwon province (sample size of each (n) = 5). The samples obtained were in a state that did not require an additive mechanical process in order to cook. In a separate experiment, five samples of the paddy rice (*Oriza sativa* L. Odae) obtained from Hwacheon, Korea were dehulled to brown rice. The brown rice was milled to various degrees of milling (9.0, 11.0 and 12.5%, based on brown rice). 12.5 "milling ratio" is commercially available as polished rice (Baekmi in Korean). Milling ratio was determined using the equation: (1-[weight(g) of milled rice/weight(g) of brown rice] x 100.

Analysis

The phytic acid content of each sample was determined using the colorimetric method reported by Latta and Baskin (1980), but as modified by Vaintraub and Lapteva (1998). Briefly, ground samples were extracted under magnetic agitation with 2.4% HCl solution overnight at room temperature. The suspension was centrifuged at 3,500 rpm for 30 min and the supernatant was filtered. The phytate was assayed in appropriately diluted supernatant. One mL of Wade's reagent (0.03% solution of $FeCl_3 \cdot 6H_2O$ containing 0.3% sulfosalicylic acid) was added to 3.0 mL of the assay solution and the mixture was centrifuged. The absorbance at 500 nm was measured. Samples were analyzed in duplicate with coefficients of variation (mean <5%). The recoveries of phytic acid during extraction were determined by spiking with the authentic compounds at similar levels to those of detected in samples. The mean recovery of the phytic acid was 97.0%. Moisture content was determined by drying the well ground sample to constant weight in an oven at 105℃ (AOAC, 1995). Data were expressed as wet weight basis of the sample.

Data analysis

Values are presented as mean ± standard error of the mean. Comparisons between groups were made using one way analysis of variance. The differences between means were tested using least significant differences (LSD) when the F value was significant ($P<0.05$). Also, data were analyzed by Student's t-test to examine the milling effects between the rice (Freud and Wilson, 1997).

Results and Discussion

Contents of phytic acid

The moisture and phytic acid content of various cereals are shown in Table 1. Among the several cereals, corn crop had the highest phytic acid content whereas polished barley was the lowest. Barley undergoes milling steps to an edible state as rice, whereas other grains do not need additional steps after dehusking to make them edible. Lee (1989) reported previously that phytic acid content of barley produced in Korea was 0.94-1.17% (w/w) before milling, while mechanical polishing of the barley decreased the phytic acid content of whole barley by 71-83%.

Table 1. The contents of moisture and phytic acid of various cereal crops grown in Korea.

	Moisture (%)	Phytic acid (g/100 g)
Buckwheat	12.8 ± 0.34	0.58 ± 0.05^{bc}
Foxtail Millet, nonglutinous	11.0 ± 0.48	0.75 ± 0.13^{d}
Foxtail Millet, glutinous	11.2 ± 0.71	1.03 ± 0.20^{e}
Sorghum	11.8 ± 0.54	0.71 ± 0.11^{cd}
Millet,	11.8 ± 0.22	0.44 ± 0.19^{b}
Barley (polished)	10.4 ± 0.58	0.13 ± 0.05^{a}
Job's tears	10.7 ± 0.50	1.34 ± 0.18^{f}
Corn, Yellow	12.0 ± 0.23	2.27 ± 0.06^{g}
Wheat, flour (Urimill)	12.3 ± 0.45	0.51 ± 0.08^{b}

All data are based on wet mass weight and are presented as mean ± SE (n=5).
Values with different superscripts within a row are significantly different at $P<0.05$.

We found that the phytic acid content of the various legumes was comparable (Table 2). Previous report indicated that Korean people consumed approximately soybean crops of 6.0 g/day, soybean curd of 24.5g/day, and soymilk of 6.2 g/day as legume products in 2005 (Ministry of Health and Welfare of Republic of Korea, 2006).

Table 3 shows the phytic acid content in differently processed white rice. Brown rice had the highest phytic acid content among the rices in similar with our previous data (Lee *et al*., 1997). Interestingly, the phytic acid content of black rice was four times higher than white rice, whereas the phytic acid content of glutinous white rice was comparable to that of unglutinous white rice.

In general, brown rice is gradually polished to make white rice for general use by milling, eliminating the bran and the outer layer of the rice grain (Liang *et al*., 2008). As seen in Table 3, the phytic acid content of brown rice decreased as milling steps were further processed.

The polishing of rice may decrease not only phytic acid content, but also mineral and dietary fiber content (Doesthale *et al*., 1979; Liang *et al*., 2008). In this study, the phytic acid content of 100% polished rice was reduced to 19.2% of brown rice. In a previous study, we found that the calcium, magnesium, iron and zinc contents of polished rice were equivalent to 40, 23, 28 and 73% of their respective levels in brown rice (Lee *et al*., 1997). Meanwhile, Kim *et al*. (2004) reported that the Ca, Mg, Fe and Zn contents of polished rice were 66, 35, 61 and 71% of their respective levels in brown rice harvested in Korea. These suggest that the technical differences in the polishing process may in part determine some mineral contents of the rice (Roberts, 1979).

Antioxidant function of phytic acid could be a good nutrition factor in preventing age-related diseases such as hyperlipidemia, renal stone disease or colon cancer, especially in aged peoples (Harman, 1995).

Recently, Li *et al*. (2008) has developed low phytate content of rice cultivar. Brown rice of the new rice cultivar had 0.46% phytic acid, compared to 0.9% of the parental cultivar, but there were no differences in the mineral contents between new rice and parent cultivar. Low phytate cultivars may be beneficial to improve the nutritional value of cereals such as minerals (Raboy *et al*., 2001).

Table 2. The contents of moisture and phytic acid of several legume crops grown in Korea.

	Moisture (%)	Phytic acid (g/100 g)
Red indian bean	12.1 ± 1.19	1.12 ± 0.09
Black indian bean	12.7 ± 0.96	1.16 ± 0.04
Mung bean	11.2 ± 0.64	1.03 ± 0.04

All data are based on wet mass weight and are presented as mean ± SE (n=5).

Table 3. The contents of moisture and phytic acid in some rice (*Oriza sativa* L.) milled to different degrees.

	Moisture (%)	Phytic acid (g/100 g)
Brown rice (unglutinous, white)	12.2 ± 1.09	1.05 ± 0.19
Rice (Milling ratio*9)	12.5 ± 0.89	0.47 ± 0.09*
Rice (Milling ratio 11)	12.6 ± 0.54	0.27 ± 0.10*
Polished rice (Milling ratio 12.5)	12.9 ± 0.59	0.20 ± 0.04*
Polished rice (glutinous, white)	12.1 ± 0.50	0.23 ± 0.08*
Polished rice (black)	11.4 ± 0.47	0.82 ± 0.06

All data are based on wet mass weight and are presented as mean ± SE (n=5).
*Significantly different (p<0.05) from the brown rice (unglutinous, white).
Brown rice was further milled to different degrees. *Milling ratio "1" means the removal of 8 % surface layer including aleuronic layer from brown rice as bran.

Daily intake of phytic acid

Kwun and Kwon (2000) reported the estimated daily phytate intake of the average Korean to be 1,677 mg/day in 1995, 39% of which was from rice (653 mg/day). Soybean products supplied 22% of total daily intake of the phytic acid (373 mg/day). Over the past several years, dietary pattern of Korean has dynamically shifted from a traditional diet to more Westernized diet as a consequence of national economic growth (Kim *et al*., 2000).

According to the Report of the Ministry of Health and Welfare of the Republic of Korea (2006), the per capita intake of rice of Korean was 205 g/day in 2005, which is equivalent to approximately 430 mg of phytic acid a day as basis of our present data. During the same period, the consumption of cereals except rice did not change greatly (Kim *et al*., 2000). Although the consumption of vegetables was increased from

285 g/day in 1995 to 327 g/day in 2005, fruit consumption decreased from 146 g/day in 1995 to 87 g/day in 2005. The consumption of legumes and their products increased slightly from 35 g/day to 39 g/day (mainly due to the increased consumption of soymilk) on the same period, equivalent to the daily intake of phytic acid of about 8.6 mg, suggesting that the amount of phytic acid increased by a rise in the consumption of the legume products during the period was marginal (Kim *et al*., 1994).

Thus, the intake of phytic acid should reflect principally the reduced consumption of rice. From this presumption, the phytic acid intake of the average Korean might be estimated to be about 1,450 mg/day in 2005.

In conclusion, we have determined the phytic acid content of cereals produced in Korea, which will be useful not only for estimating the daily intake of phytic acid from cereals, but also to study the bioavailability of minerals to Korean due to the interaction between minerals and phytate. We suggest that the decreased daily intake of phytic acids in Korean was occurred due to the reduced rice consumption.

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