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RESEARCH NOTE

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Changes in Oxalate and Phytate Concentrations During Soymilk Processing from the Seeds of Korean Soybean Cultivars

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Abstract A high dietary oxalate intake may lead to calcium oxalate (CaOx) kidney stones in the gastrointestinal tract. Most soy foods contain high concentrations of oxalate and/or phytate. This study analyzed the changes in oxalate (Ox), phytate ($InsP_6$), and calcium (Ca) during soymilk processing from the seeds of Korean recommended soybean cultivars (cvs). The contents of Ox, $InsP_6$, and Ca in 21 cvs ranged from 14, 108, and 148 to 231, 279, and 246 mg/100 g of dry seed, respectively. Seven cultivars were selected from the 21 cvs by the distributions of Ox, $InsP_6$, and Ca. Then, each contents of soymilk prepared from the 7 cvs were determined. All contents were lower in soymilk than in seeds, but the Ox to $InsP_6$ ratios changed from varying ratios (0.1-0.8) to normal ratios (0.8-1.0) in all cvs except 'Paldalkong'. Consequently, during soymilk processing, the Ox content was decreased and the $InsP_6$ content was remained higher than the Ox content although the Ox was likely to be less reductive than the $InsP_6$. These results may provide better information for minimizing the risk of formation of CaOx kidney stones due to consumption of soy products.

Keywords: soybean cultivar, soymilk, oxalate, phytate, kidney stone

Introduction

The human consumption of soybeans and products made from them is increasing due to the reported health benefits of eating soybeans in various prepared forms (1). Soybeans are regarded as a highly nutritious food source because of their excellent content of oil and protein (8 essential amino acids). Soybean oil contains high concentration of essential fatty acids as well as tocopherols and, thus, is considered as one of the highly functional edible oils (2). And soybean proteins are composed of 2 major components, glycinin (11S globulin) and β-conglycinin (7S globulin). Glycinin plays an important role in the functional properties of soybean protein (3,4). In addition to these nutritional benefits, soybean seeds are rich in isoflavones that are known to prevent osteoporosis, cancer, and cardiovascular disease (5-7). However, the recent finding that soybeans and soy foods have relatively high concentrations of oxalate (Ox) is a cause of concern regarding the risk of kidney stones for humans consuming soy foods.

Ox forms water-soluble salts with Na^+, K^+, and NH_4^+ ions, and also binds to Ca^{2+}, Fe^{2+}, and Mg^{2+}, rendering these minerals unavailable (8). Ox binds to calcium (Ca) in human urine to form a poorly soluble salt that is typically near saturation. The formation of small crystals occurs when the urinary Ca and Ox concentrations reach supersaturation. A kidney stone forms when the calcium oxalate (CaOx) crystals aggregate or deposit on a 'seed' crystal, such as uric acid (9). About 2-8% of the Ox in ingested soy foods is absorbed and excreted in the urine by healthy humans (10). Kidney stones formers exhibit a higher rate of Ox absorption than nonstone formers (11), and the increase in urinary Ox following the consumption of soy foods may be large enough to increase the risk of CaOx precipitation in the former group, potentially increasing their risk of kidney stones.

Soybeans also contain high concentrations of phytate ($InsP_6$). $InsP_6$ is a fully phosphorylated form of inositol (*myo*-inositol hexakisphosphate), a compound that also exists in seeds, and has both beneficial and detrimental effects on human nutrition and health (12,13). Similar to Ox, $InsP_6$ can be synthesized by the human body. However, like Ox, the main source of $InsP_6$ for humans is plant foods. $InsP_6$ has long been considered an antinutrient due to its ability to complex metal ions, including zinc (14), calcium (15), and iron (16-19), reducing their bioavailability. However, $InsP_6$ has recently been proposed to reduce kidney stone formation by inhibiting the formation of CaOx and Ca phosphate crystals (20).

Soymilk, a popular food in the traditional Asian diet, is obtained by squeezing the homogenate of water-soaked soybeans. During the processing of soymilk, soybeans are soaked and then heated to 100°C for a period of time (21,22). Al-Wahsh *et al.* (23) reported that soy foods containing low concentrations of oxalate and moderate concentrations of phytate may be advantageous for kidney stone patients or persons with a high risk of kidney stones. Therefore, an analysis of changes in the Ox and $InsP_6$ concentrations during the soymilk processing from soybean seeds would be useful to identify soy foods that are nutritionally advantageous for kidney stone patients or persons at risk for kidney stone formation. However, there have been very few reports of changes in the Ox and $InsP_6$ concentrations during the transition from soybean seeds to soymilk, although there have been reports of the

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concentrations of Ox and $InsP_6$ in selected commercial soy foods, soybeans, soymilks, and various vegetables. In this study, to present information for safe digestion of soybean cultivars (cvs) and soy food, we selected 7 soybean cvs from 21 Korean recommended soybean cvs based on their Ox, $InsP_6$, Ca, and Mg contents, prepared soymilk from seeds of the 7 cvs, and investigated the changes in the concentrations of Ox, $InsP_6$, and Ca during soymilk processing.

Materials and Methods

Materials Seeds of 21 recommended Korean soybean cvs [*Glycine max* (L.) Merr.], produced in 2005, were obtained from a local farm in Korea. The cvs were composed of 1) 'Paldalkong', 2) 'Dankyongkong', 3) 'Sinpaldalkong', 4) 'Kwangkyokong', 5) 'Changyupkong', 6) 'Hwangkeumkong', 7) 'Baekwoonkong', 8) 'Eunhakong', 9) 'Daewonkong', 10) 'Bukwangkong', 11) 'Changkyongkong', 12) 'Bangsakong', 13) 'Saealkong', 14) 'Duckyoukong', 15) 'Danyeobkong', 16) 'Namhaekong', 17) 'Marikong', 18) 'Taekwangkong', 19) 'Muhankong', 20) 'Solokkong', and 21) 'Danbeakkong'. Hydrochloric acid, sulfuric acid solution, sulfosalicylic acid, and ferric chloride for oxalate analysis were purchased from Sigma-Aldrich (St. Louis, MO, USA).

Oxalate analysis of soybean and soymilk One g samples of soybean seeds were prepared by grinding in a Philips grinder (HR-2870; Philips, China) and filtering with a 100-mesh sieve. Soymilk samples of 10 g were used. The Ox contents of soybeans and soymilk were analyzed according to the procedures of Savage *et al.* (8) and Kim *et al.* (24), with some modifications. For the total Ox, each sample was placed in a 50-mL beaker, 30 mL of 2 N HCl were added, and the samples were homogenized at 16,000 rpm for 1 min using a rolling chopper-type polytron homogenizer (Ultra Turrax T25; IKA Lab. Co., Kuala Lumpur, Malaysia). Then, the beakers were shaken in a water bath at 80°C for 15 min, and the extracts were allowed to cool and filtered with Whatman filter paper (8 μm, No. 2; Whatman, Maidstone, England). The filtrates were transferred quantitatively to 100-mL volumetric flasks and the volume brought to 100 mL with 2 N HCl. The samples were then diluted 10-fold with distilled water and filtered with 0.45-μm regenerated cellulose microfilters (Sartorius AG, Göttingen, Germany). The amounts of total Ox in the filtrates were measured using high performance liquid chromatography (HPLC; Thermo Separation Products, Waltham, MA, USA). An Aminex HPX-87H ion exclusion column (300×7.8 mm i.d.; Bio-Rad, Hercules, CA, USA) and a Micro-Guard Cation H cartridge (30×4.6 mm, Bio-Rad) were used as the solid phase. The mobile phase was 0.008 N H_2SO_4 solutions and the flow rate was 0.6 mL/min, and the signal at 215 nm was monitored using a ultraviolet (UV) detector (Spectra System UV1000; Thermo Separation Products) for the total Ox solution. Injection volumes of 20 μL were delivered using an autosampler (Spectra System AS1000; Thermo Separation Products), and quantitation was performed by electronic integration of the peak area using MultiChro™ Version 5.0 (Yullin Technology, Seoul, Korea). For the extraction of soluble Ox, distilled water was used as the extraction medium instead of 2 N HCl. The insoluble Ox concentration was calculated by subtracting the soluble Ox from the total oxalate. All measurements were performed in triplicate.

Phytate analysis of soybean and soymilk Two g samples of soybean seeds were prepared by grinding in a Philips grinder and filtering with a 100-mesh sieve. Soymilk samples of 20 g were used. The amounts of $InsP_6$ in the soybeans and soymilk were measured according to the method of Haug and Lantzsch (25), with some modifications based on the method of Mameesh and Tomar (26). Briefly, each sample was transferred quantitatively to a 50-mL volumetric flask, and made up to 50 mL with 0.2 N HCl containing 5% Na_2SO_4 to solubilize the $InsP_6$. The mixture was filtered with Whatman filter paper (20-25 μm, No. 4, Whatman), and 10 mL of the filtrate was diluted to 40 mL. Ten mL of the diluted filtrate were mixed with 12 mL of ferric chloride solution (10 mM $FeCl_3 \cdot 6H_2O$ in 0.2 N HCl solution). The mixture was heated in a boiling water bath for 75 min, cooled in an ice bath for 15 min, and centrifuged (2,500×g, 30 min) to precipitate any ferric phytate formed during the reaction. The supernatant was filtered with Whatman filter paper (8 μm, No. 1, Whatman), and the filtrate was transferred to a 50-mL volumetric flask, and made up to 50 mL with distilled water. The $InsP_6$ in the diluted filtrate was determined by a colorimetric method using Wade's reagent [0.03%(w/v) $FeCl_3 \cdot 6H_2O$ and 0.3%(w/v) sulfosalicylic acid in distilled water]. One mL of Wade's reagent was added to 3 mL aliquots of each sample, and the samples were mixed on a vortex mixer for 5 sec. The absorbance of each sample was determined at 500 nm against a water blank using a spectrophotometer (UV-1650PC; Shimadzu, Kyoto, Japan). A standard curve was prepared using sodium phytate. All measurements were performed in triplicate.

Mineral analysis of soybean and soymilk The amounts of divalent minerals such as Ca and Mg were analyzed because of their presumed association with Ox and $InsP_6$ and their utilization in the manufacture of soy foods. The Ca and Mg contents of soybeans and soymilk were analyzed according to the procedures of Al-Wahsh *et al.* (23) and Lachas *et al.* (27), with some modifications. Two g of soybean cvs were grinded using a Philips grinder. The resulting powders and soymilk powders dried from 20 g of each soymilk solution using a drying oven were burned at 550°C until the samples became light ash in color. The burned soybean and soymilk ashes were adjusted to 10 mL with 0.5 N HNO_3 and then filtered using GF/C filter paper. The mineral concentrations in each filtrate were determined using an inductively coupled argon plasma spectrometer system (ICAP 61E; Thermo Jarrell Ash, Franklin, MA, USA). All measurements were performed in triplicate.

Soymilk preparation Soymilk was prepared from soybeans using the method of Toda *et al.* (28). Soybeans (120 g/batch) were washed 3 times with distilled water and soaked in distilled water at 25°C for 18 hr. The hydrated seeds were drained and ground into homogenates using a rolling chopper-type polytron homogenizer with distilled water equivalent to 10 times the weight of the dry seed. Raw soymilk was separated using filter cloth (100-mesh).

Soymilks were prepared by incubating raw soymilk in boiling water for 5 min followed by cooling in flowing water. The soymilks were incubated at 4°C until the measurement of Ox, $InsP_6$, Ca, and Mg.

Statistical analysis All treatments were replicated 3 times, and samples were analyzed in duplicate. The values presented are averages of triplicates. Significant differences between the sample means were determined at the $p<0.05$ level by analysis of variance (ANOVA) using SAS version 8.2 (SAS Institute Inc., Cary, NC, USA).

Results and Discussion

Oxalate, phytate, calcium, and magnesium contents of Korean soybean cultivars The relative distributions of the total Ox, $InsP_6$, and Ca contents in the seeds of 21 Korean recommended cvs were shown in Fig. 1. The total Ox contents of the seeds varied widely, from 13.8 to 231.2 mg/100 g of dry seed, whereas the Ca contents were distributed in a narrow range from 148 to 245 mg/100 g of dry seed. The total Ox contents were similar to the range of 82 to 285 mg/100 g reported by Horner *et al.* (29), whereas the Ca contents were somewhat lower than the range of 185 to 389 mg/100 g reported by Massey *et al.* (30). The total $InsP_6$ contents ranged from 0.11 to 0.28 g/100 g of dry seed, which is lower than the ranges in soybean reported by Horner *et al.* (0.77-2.22 g/100 g of dry seed) (29) and Raboy *et al.* (1.39-2.3 g/100 g of dry seed) (31). There was no relationship between the total Ox, total $InsP_6$, and Ca concentrations in the cvs studied. On the basis of Ox concentrations and absorption, Grentz and Massey (32) reported that frequent consumption of soy products may increase the excretion of Ox to more than 40 mg/day, which is defined as hyperoxaluria and may lead to kidney stone formation. In addition, because Ox may also reduce mineral absorption (12), excess consumption raises the potential for mineral deficiencies. Therefore, we postulated that a lower Ox content and/or a higher $InsP_6$ content in soy foods would be beneficial for decreasing the potential risk of oxalate kidney stones and other disorders with the ingestion of soy foods. However, Massey *et al.* (30) and Al-Wahsh *et al.* (23) reported that the total Ox content in soy products is much lower than in commercial soybean seeds. These reports suggested that the total Ox content in soybean decreases during the manufacture of soy foods. Therefore, we wondered whether the potential risk of the consumption of Korean cvs would decrease with soy food processing.

Selection of 7 cultivars for soymilk preparation To investigate changes in the Ox, $InsP_6$, and Ca contents during the soymilk processing from soybean seeds, 7 cvs were selected from 21 Korean recommended cvs based on

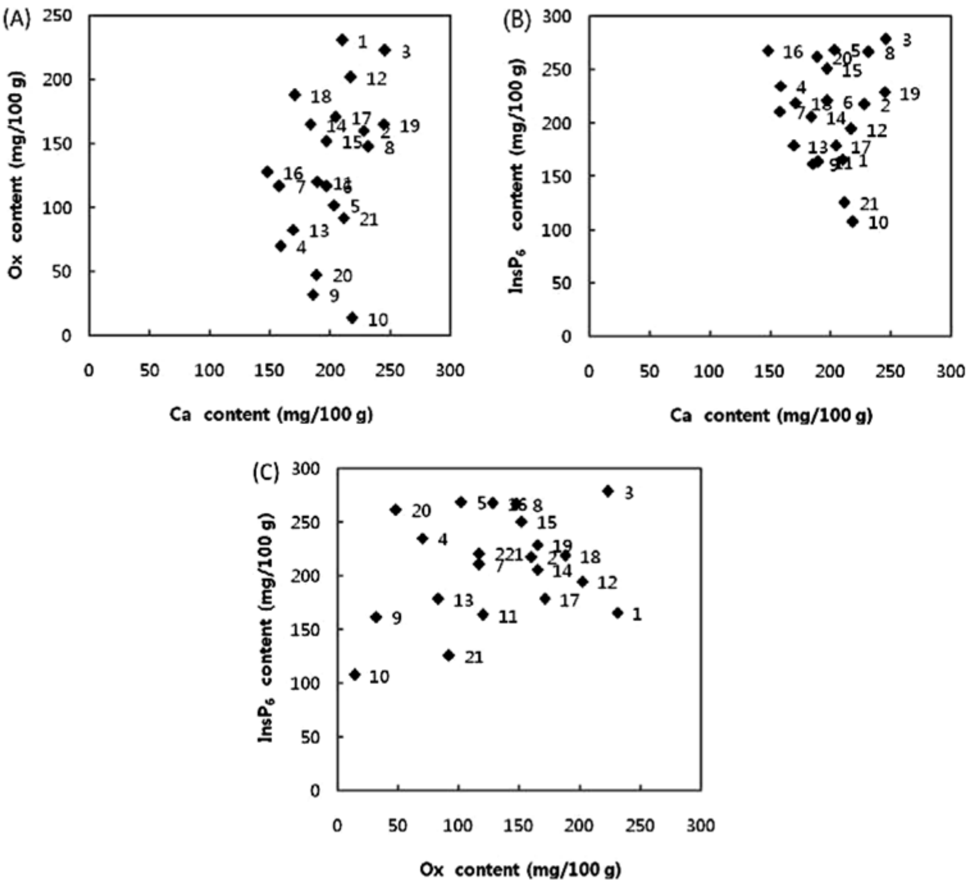

Fig. 1. Correlation between (A) Ox and Ca, (B) $InsP_6$ and Ca, and (C) $InsP_6$ and Ox in the seeds of 21 Korean recommended soybean cultivars.

Table 1. Total oxalate (Ox), insoluble Ox, soluble Ox, phytate ($InsP_6$), divalent mineral concentrations, and Ox/$InsP_6$ and Ox/Ca ratios in seeds of 7 soybean cultivars

Cultivar	Total Ox (mg/100 g)	Insol Ox (mg/100 g)	Sol Ox (mg/100 g)	$InsP_6$ (mg/100 g)	Ca (mg/100 g)	Mg (mg/100 g)	Ox:$InsP_6$ ratio	Ox:Ca ratio
'Paldalkong'	231.2±18.5[a1)]	217.0±18.8[a]	14.2±3.2[a]	166.4±11.5[c]	210.2±12.5[bc]	137.8±8.9[c]	1.4±0.15	1.1±0.11
'Sinpaldalkong'	222.8±16.7[a]	206.9±17.3[a]	15.9±4.5[a]	279.3±21.3[a]	245.6±18.9[a]	166.3±10.2[b]	0.8±0.09	0.9±0.10
'Daewonkong'	31.8±8.9[e]	19.3±9.4[e]	12.5±3.1[a]	162.4±8.5[c]	185.7±15.4[d]	143.0±7.9[c]	0.2±0.06	0.2±0.05
'Bukwangkong'	13.8±4.5[f]	0.4±5.2[f]	13.3±2.6[a]	107.7±10.7[d]	218.4±21.0[b]	180.7±11.9[a]	0.1±0.04	0.1±0.02
'Danyeobkong'	152.4±13.5[b]	138.6±14.1[b]	13.8±4.1[a]	250.5±21.5[b]	196.9±18.5[cd]	149.0±14.6[c]	0.6±0.08	0.8±0.10
'Namhaekong'	128.5±14.3[c]	114.9±14.5[c]	13.6±2.4[a]	268.1±22.6[ab]	148.0±10.5[e]	149.5±10.3[c]	0.5±0.07	0.9±0.11
'Solokkong'	48.1±6.3[d]	35.2±6.9[d]	13.0±2.8[a]	262.0±9.9[ab]	188.7±14.2[d]	142.2±9.8[c]	0.2±0.03	0.3±0.04

[1)]Means in the same column followed by the same letter are not significantly different ($p<0.05$) as determined by Duncan's multiple range test.

Table 2. Oxalate (Ox), phytate ($InsP_6$), divalent mineral concentrations, and Ox/$InsP_6$ and Ox/Ca ratios in soymilks made from 7 soybean cultivars

Cultivar	Ox (mg/100 g)	$InsP_6$ (mg/100 g)	Ca (mg/100 g)	Mg (mg/100 g)	Ox:$InsP_6$ ratio	Ox:Ca ratio
'Paldalkong'	30.7±5.6[a1)]	27.8±6.1[a]	71.4±8.6[a]	34.5±5.4[b]	1.1±0.31	0.4±0.09
'Sinpaldalkong'	29.1±5.9[a]	32.8±5.2[a]	44.4±6.4[bc]	32.9±6.1[bc]	0.9±0.23	0.7±0.16
'Daewonkong'	31.2±6.8[a]	30.6±11.7[a]	28.5±5.9[d]	10.7±3.9[d]	1.0±0.45	1.1±0.33
'Bukwangkong'	31.9±5.1[a]	34.7±5.3[a]	38.0±8.7[c]	31.6±6.2[bc]	0.9±0.20	0.8±0.23
'Danyeobkong'	32.6±8.2[a]	34.8±12.7[a]	53.7±10.0[b]	63.7±10.2[a]	0.9±0.42	0.6±0.19
'Namhaekong'	28.7±6.3[a]	36.8±15.2[a]	23.9±4.1[d]	23.9±7.7[c]	0.8±0.36	1.2±0.34
'Solokkong'	27.3±3.9[a]	32.8±4.2[a]	49.2±5.7[b]	33.4±8.6[b]	0.8±0.16	0.6±0.10

[1)]Means in the same column followed by the same letter are not significantly different ($p<0.05$) as determined by Duncan's multiple range test.

their Ox, $InsP_6$, and Ca contents. Table 1 showed the concentrations of total Ox, $InsP_6$, divalent minerals such as Ca and Mg, and the total Ox/$InsP_6$ and total Ox/Ca ratios in soybeans of the 7 selected cvs. The total Ox and insoluble Ox contents of seeds of the 7 cvs ranged from 13.8 and 0.4 to 231.2 and 217.0 mg/100 g of dry seed, respectively, whereas the soluble Ox contents ranged from 12.5 to 15.9 mg/100 g dry seed. The soluble Ox contents were similar to the range of 14.7 to 29.9 mg/100 g reported by Massey *et al.* (30). The total Ox contents in 'Paldalkong' and 'Sinpaldalkong' were higher than those in seeds of the other cvs, but the soluble Ox contents were lower. The percentages of soluble Ox contents in the soybean seeds were in the low range of 6.2 to 10.6%, except for 'Daewonkong' and 'Bukwangkong'. The $InsP_6$ contents ranged from 107.7 to 279.3 mg/100 g of dry seed, and the Ca and Mg concentrations ranged from 148.0 and 137.8 to 245.6 and 180.7 mg/100 g of dry seed, respectively. The $InsP_6$ and Ca contents in 'Shinpaldalkong' were the highest among the 21 cvs, and the $InsP_6$ content in 'Bukwangkong' and the Ca content in 'Namhaekong' were the lowest. There was no correlation between the total Ox and $InsP_6$ within or among the 7 cvs, and no significant relationships of Ca and Mg in any of the cvs. The ratio of Ox to $InsP_6$ in the 'Paldalkong' and 'Sinpaldalkong' cvs was higher than reported elsewhere (23,29), and the ratios of Ox to $InsP_6$ and Ox to Ca in 'Bukwangkong' and 'Solokkong' were much lower than those in other soybean seeds. These results showed that the potential risk of kidney stones from Korean soybean cvs such as 'Paldalkong' and 'Sinpaldalkong' were somewhat higher than that indicated by other reports (23,29). The recommended soybean cvs, including 'Bukwangkong', 'Solokkong', 'Paldalkong', and 'Sinpaldalkong', are commonly consumed in Korea. Therefore, the consumption of soybean seeds, especially of the 'Paldalkong' and 'Sinpaldalkong' cvs, requires processing into products such as soymilk and *tofu* in order to decrease the potential risk of kidney stones from these cvs.

Oxalate, phytate, calcium, and magnesium contents of soymilk The concentrations of total Ox, $InsP_6$, and divalent minerals including Ca and Mg, and the ratios of total Ox/$InsP_6$ and total Ox/Ca in soymilk are shown in Table 2. The total Ox and $InsP_6$ contents ranged from 27.3 and 27.8 to 32.6 and 36.8 mg/100 g of liquid soymilk, respectively, and the Ca and Mg contents ranged from 23.9 and 10.7 to 71.4 and 63.7 mg/100 g of liquid soymilk, respectively. The contents of all of these components of soybean seeds were reduced during soymilk processing. The widely varying distributions of the Ox and $InsP_6$ contents in soybean seeds were in contrast to the regular distributions in the resulting soymilks. These results are similar to the consistent distributions and low contents of Ox in commercial soy foods reported by Al-Wahsh *et al.* (23) and Massey *et al.* (30). The conversion into regular distributions of Ox contents during the transition from soybean seed to soymilk may be related to the extraction of soluble Ox during the heat treatment step of soymilk processing based on the other reports (23,30) and the regular distribution of soluble Ox in soybean seed.

The ratios of Ox to $InsP_6$ in soymilk prepared with seeds of most of the soybean cvs, except 'Paldalkong', increased into the regular range (0.8-1.0) from the more widely varying range (0.1-0.8) in soybean seeds, whereas the ratios of Ox to Ca in soymilk remained in a large range from 0.4 to 1.2 (Table 2). These results suggested that the potential risk of oxalate kidney stones during soymilk processing is decreased because the Ox content was decreased, and the $InsP_6$ content related to the inhibition of CaOx was still higher than Ox content related to the formation of CaOx although the Ox content is less reductive than the $InsP_6$ content. However, the Ca content, related to the formation of CaOx, was transferred, to varying extents, into soymilk.

Even though CaOx is poorly absorbed, not all Ox in soy is bound to Ca. Ox that is not bound to Ca is assumed to be bound to potassium and/or sodium and is referred to as soluble Ox, as these salts have solubilities in the range of 2.5 to 16.7 g/100 mL (33). The potential outbreak rate of oxalate kidney stones increased with increase of amounts and duration of Ox intake (10). However, controlling the intake period of soy products is difficult because these products are frequently ingested in Asian countries. Therefore, the use of low-Ox seeds and the control of the Ox and $InsP_6$ contents during soy processing may be suitable methods for reducing the potential risks of soybean seeds and soy products. Consumption of the recommended Korean soybean cvs such as 'Namhaekong' and 'Solokkong', especially in processed form, could reduce the potential risk, because the ratio of Ox to $InsP_6$ is low in both the seeds and soymilk of these cvs.

In conclusion, Ox and Ca, which were related to the formation of CaOx and, consequently, to oxalate kidney stones, were abundant in soybean seeds; additionally, $InsP_6$, which was related to the inhibition of CaOx formation, was also abundant (23,29). Therefore, generally, the possibility of CaOx formation after the digestion of soybean seeds was very lower. However, the outbreak rate of oxalate kidney stones increased with increase of Ox intake and duration of Ox consumption. In soybean seeds used in this study, the Ox content was found to vary more than the $InsP_6$ content, but all were high compared to the recommendations for patients with oxalate kidney stones. Currently, they are advised to limit their intake of foods containing >10 mg/serving, with a total intake not to exceed 50-60 mg/day (30). Therefore, the long-term intake of soybean with a high Ox content could lead to a greater risk of oxalate kidney stones, more so than consuming soybean with a high $InsP_6$ content in patient and people with a history of oxalate kidney stone (10).

During the preparation of soymilk from soybean seeds, the Ox and $InsP_6$ contents were found to decrease into a regular range, and the ratios of Ox to $InsP_6$ in most of the soybean cvs, except 'Paldalkong', were increased because the Ox content was less reductive than the $InsP_6$ content, but the $InsP_6$ content was still higher than Ox content. In contrast, the Ca content, related to the formation of CaOx, was transferred into soymilk in a more varying manner. Therefore, the potential risk of oxalate kidney stones with the consumption of soymilk is likely to be lower than with soybean seeds, because of the increased possibility that the Ox content is decreased and the inhibition of CaOx is more active than the formation of CaOx. In this sense, the Korean recommended soybean cultivar such as 'Namhaekong' and 'Solokkong' were suitable for use in soy processing to reduce potential risks, as the ratio of Ox to $InsP_6$ in these cvs is low in both the seeds and the soymilk. Consequently, we proposed it was effective method for the safe intake of soy food that soybean seeds with low Ox content used in the digestion of soybean and soy products.

This study demonstrated changes in the Ox, $InsP_6$, and Ca contents that occur during the processing of seeds of Korean soybean cvs into soymilk. These results may be providing better information of how to breed and select optimal soybean cvs and useful as guidelines in the manufacture of soy products, with a view to minimizing the risk of oxalate kidney stones following the consumption of soy products.

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References

1. Messina M. Soyfoods: Their role in disease prevention and treatment. pp. 442-477. In: Soybeans. Chemistry, Technology, and Utilization. Liu K (ed). International Thomson Publishing, New York, NY, USA (1997)
2. Chung JS, Choe EO. Effect of sesame oil on thermooxidative stability of soybean oil. Food Sci. Biotechnol. 10: 446-450 (2001)
3. Kim CS, Ko KC, Lee SP. Enhanced emulsifying activity of soybean proglycinin modified by protein engineering. Food Sci. Biotechnol. 8: 184-188 (1999)
4. Kim SL, Koo HM, Chun SC, Kim JT, Kim MY, Chi HY, Kim EH, Kim HB, Kim MJ, Seo BR, Kang EY, Seo SH, Chung IM. Characterization of 7S and 11S globulins in soybean varieties differing in seed size and their effects on the properties of soybean curd. Food Sci. Biotechnol. 17: 135-143 (2008)
5. Food and Drug Administration. Health Claim for soy protein and coronary heart disease. Available from: http://www.cfsan.fda.gov/~lrd/cf101-82.html. Accessed June 12, 2008.
6. Messina MJ. Legumes and soybeans: Overview of their nutritional profiles and health effects. Am. J. Clin. Nutr. 70: 439S-450S (1999)
7. Kim WC, Kwon SH, Rhee IK, Hur JM, Jeong HH, Choi SH, Lee KB, Kang YH, Song KS. Rapid high performance liquid chromatographic quantification of major isoflavones in soybean and soybean pastes. Food Sci. Biotechnol. 15: 24-27 (2006)
8. Savage GP, Vanhanen L, Mason SM, Ross AB. Effect of cooking on the soluble and insoluble oxalate content of some New Zealand foods. J. Food Compos. Anal. 13: 201-206 (2000)
9. Robertson WG, Peacock M. The cause of idiopathic calcium stone disease: Hypercalciuria or hyperoxaluria. Nephron 26: 105-110 (1980)
10. Massey LK, Grentz LM, Horner HT, Palmer RG. Soybean and soy food consumption increase oxalate excretion. Top. Clin. Nutr. 17: 49-59 (2002)
11. Chai W, Liebman M, Kynast-Gales S, Massey L. Oxalate absorption and endogenous oxalate synthesis from ascorbate in calcium oxalate stone formers and nonstone formers. Am. J. Kidney Dis. 44: 1060-1069 (2004)
12. Gillooly M, Bothwell T, Torrance J, MacPhail A, Derman A, Bezwoda W, Mills W, Charlton R, Mayet F. The effects of organic acids, phytates, and polyphenols on the absorption of iron from vegetables. Brit. J. Nutr. 49: 331-342 (1983)
13. Vacenik I, Shamsuddin A. Cancer inhibition by inositol hexakisphosphate (IP_6) and inositol: From laboratory to clinic. J. Nutr. 133: 3778S-3784S (2003)
14. Reinhold J, Nasr K, Lahimgarzadeh A, Hedayati H. Effects of purified phytate and phytate-rich bread upon metabolism of zinc, calcium, phosphorus, and nitrogen in man. Lancet 1: 283-288 (1973)
15. Heaney R, Weaver CM. Oxalate: Effect on calcium absorbability.

Am. J. Clin. Nutr. 50: 830-832 (1989)
16. Reddy MB, Hurrell RF, Juillerat MA, Cook JD. The influence of different protein sources on phytate inhibition of nonheme-iron absorption in humans. Am. J. Clin. Nutr. 63: 203-207 (1996)
17. Hurrell RF, Juillerat MA, Reddy MB, Lynch SR, Dassenko SA, Cook JD. Soy protein, phytate, and iron absorption in humans. Am. J. Clin. Nutr. 56: 573-578 (1992)
18. Lynch SR, Dassenko SA, Cook JD, Juillerat MA, Hurrell RF. Inhibitory effect of a soybean-protein-related moiety on iron absorption in humans. Am. J. Clin. Nutr. 60: 567-572 (1992)
19. Mendoza C, Viteri FE, Lonnerdal B, Young KA, Raboy V, Brown K. Effect of genetically modified, low-phytate maize on absorption of iron from tortillas. Am. J. Clin. Nutr. 68: 1123-1128 (1998)
20. Grases F, Ramis M, Costa-Bauza A. Effects of phytate and pyrophosphate on brushite and hydroxyapatite crystallization: Comparison with the action of other polyphosphates. Urol. Res. 28: 136-140 (2000)
21. Jackson CJC, Dini JP, Lavandier C, Rupasinghe HPV, Faulkner H, Poysa V, Buzzell D, DeGrandis S. Effects of processing on the content and composition of isoflavones during manufacturing of soy beverage and *tofu*. Process Biochem. 37: 1117-1123 (2002)
22. Murphy PA, Barua K, Hauck CC. Solvent extraction selection in the determination of isoflavones in soy foods. J. Chromatogr. B 777: 129-138 (2002)
23. Al-Wahsh IA, Horner HT, Palmer RG, Reddy MB, Massey LK. Oxalate and phytate of soy foods. J. Agr. Food Chem. 53: 5670-5674 (2005)
24. Kim DJ, Kim HK, Kim MH, Lee JS. Analysis of oxalic acid various vegetables consumed in Korea. Food Sci. Biotechnol. 16: 650-654 (2007)
25. Haug WG, Lantzsch HJ. Sensitive method for the rapid determination of phytate in cereals and cereal products. J. Sci. Food Agr. 34: 1423-1426 (1983)
26. Mameesh MS, Tomar M. Phytate content of some popular Kuwaiti foods. Cereal Chem. 70: 502-503 (1993)
27. Lachas H, Richaud R, Herod AA, Dugwell DR, Kandiyoti R. Determination of trace elements by inductively coupled plasma mass spectrometry of biomass and fuel oil reference materials using milligram sample sizes. Rapid Commun. Mass Sp. 14: 335-343 (2000)
28. Toda K, Ono T, Kitamura K, Hajika M, Takahashi K, Nakamura Y. Seed protein content and consistency of *tofu* prepared with different magnesium chloride concentrations in six Japanese soybean varieties. Breeding Sci. 53: 217-223 (2003)
29. Horner HT, Cervantes-Martinez T, Healy R, Reddy MB, Deardorff BL, Bailey TB, Al-Wahsh I, Massey LK, Palmer RG. Oxalate and phytate concentrations in seeds of soybean cultivars [*Glycine max* (L.) Merr.]. J. Agr. Food Chem. 53: 7870-7877 (2005)
30. Massey LK, Palmer RG, Horner HT. Oxalate content of soybean seeds (*Glycine max*: Leguminosae), soyfoods, and other edible legumes. J. Agr. Food Chem. 49: 4262-4266 (2001)
31. Raboy V, Dickinson D, Below F. Variation in seed total phosphorus, phytic acid, zinc, calcium, magnesium, and protein among lines of *Glycine max* and *G. soja*. Crop Sci. 24: 431-434 (1984)
32. Grentz L, Massey LK. Contribution of dietary oxalate to urinary oxalate in health and disease. Top. Clin. Nutr. 17: 60-70 (2002)
33. Ohkawa H. Gas chromatographic determination of oxalic acid in foods. J. Assoc. Off. Anal. Chem. 68: 108-111 (1985)