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Mineral Composition of Tofu Made from Twelve Soybean Genotypes Grown at Three Locations in USA *

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Abstract: Soyfood products like soymilk and tofu are becoming popular among consumers due to health benefits. However, effects of soybean [*Glycine max* (L.) Merr.] genotypes and growing locations on quality of tofu are not well established. The present study was conducted to determine contents of minerals in tofu prepared from 12 soybean genotypes (BARC-8, BARC-9, Enrei, Hutcheson, MD86-5788, Nakasennari, S90-1056, Suzuyutaka, V71-370, V81-1603, Ware and York) grown at three southern U.S. locations (Huntsville, Alabama; Princess Anne, Maryland; and Petersburg, Virginia) during 1995. The genotype effects on mineral composition of tofu were significant only for Zn. Growing location had significant effects on contents of P, B, Zn and Mn in tofu. Average contents of S, P, K, Mg and Ca in tofu were 0.40, 0.68, 1.76, 0.26 and 0.25 g per 100 g of tofu, respectively. In the case of B, Zn, Mn, Fe, Cu and Al, the average contents were 19.7, 62.3, 42.9, 190, 15.4 and 188 mg kg^{-1} of tofu, respectively. The contents of S and Zn were positively and those of K and Mg were negatively correlated with protein content. The contents of S, K, Ca, B and Zn were negatively correlated with oil content. Based on Daily Recommended Intake values, it was suggested that consideration may need to be given to the content of Mn given that seed produced in Maryland had considerably lower Mn content as compared to that produced in Alabama or Virginia. Seed size, generally, did not affect mineral composition of tofu.

Key words: *Glycine max* (L.) Merr. · seed size · soyfood · protein content · dietary reference intakes

INTRODUCTION

Tofu, also known as soybean curd, is a soft, cheese-like food made by curdling fresh hot soymilk with a coagulant [1]. Tofu was first used in China around 200 B.C. Today, tofu is a dietary staple throughout Asia. Tofu is known to be rich in high-quality protein. It is also a good source of B-vitamins and iron. When the curdling agent used to make tofu is calcium salt, tofu is an excellent source of calcium [1]. Soyfood products like soymilk and tofu are becoming popular among consumers due to health benefits [2-5]. Soybean breeders and tofu processors need to understand the influence of cultivar and environment on tofu quality.

Soybean genotype effects on soymilk solids, soymilk protein, soymilk color, soymilk index, tofu yield, tofu protein, tofu color and tofu index (an unweighted sum of tofu yield, tofu protein and tofu strength) were significant whereas locations significantly affected tofu strength only [6]. Additionally, soybean genotypes and also growing locations significantly affected oil as well as some saturated or unsaturated fatty acids of tofu [7]. However, effects of soybean genotypes and growing locations on mineral composition of tofu are, generally, unknown.

The objectives of this study were to characterize effects of soybean genotypes and growing locations on mineral composition of tofu. In addition, we were also

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interested in comparing the mineral composition of tofu produced in our study with that of the standard reference [8] which is a generalized composition of various foods maintained by US Department of Agriculture. Our study also identified the optimal soybean genotype and growing location for ideal tofu mineral quality.

MATERIALS AND METHODS

Twelve soybean genotypes included in these studies consisting of Hutcheson (PI-518664), Nakasennari (PI-507079), Enrei (PI-385942), Suzuyutaka (PI-561395), BARC-8 (PI-555398), BARC-9 (PI-555399), York (PI-553038), Ware (PI-548627), V71-370, V81-1603, MD86-5788 and S90-1056 were sown during 1995 at three locations (Huntsville, Alabama; Princess Anne, Maryland and Petersburg, Virginia) in order to investigate the effect of different soybean genotypes as well as growing locations on mineral composition of tofu. A randomized complete block design with four replications was used at each location. Seeds from four replications from each location were bulked for tofu preparation resulting in thirty six seed samples (Twelve genotypes×three locations). These seed samples were used for tofu preparation.

The tofu was prepared by Illinois Crop Improvement Association, Inc., Champaign, Illinois, USA. The tofu preparation procedure was as follows: Eighty grams of ground soybeans were blended with 430 ml of distilled water at 65°C to produce a slurry which was further cooked with steam until the temperature reached 98°C. This temperature was held for 4 min. The cooked slurry was cooled with running tap water and strained through a centrifugal fruit juice extractor to obtain soymilk. The soymilk was filtered into a graduated flask with four layers of No. 20 bleached gauze cheese cloth and the milk was squeezed out. The soymilk was filtered with miracloth using a vacuum pump and degased before recording soymilk yield. To prepare tofu, 10% GDL (Glucono Delta Lactone) coagulant solution was added to the soymilk. This mixture was cooked in 85°C water bath for 45 min, allowed to cool at room temperature for 45 min and refrigerated overnight to obtain tofu.

The proximate analysis and contents of various minerals were determined from freeze-dried tofu samples by A and L Eastern Laboratories, Richmond, Virginia, USA.

Data on proximate analysis traits and mineral composition were analyzed, to compare genotypes and locations, using Analysis of Variance and correlation procedures in version 6.11 of SAS [9]. The statistical significance of genotypes and locations was tested by using genotype×location mean squares as the error term at the 5% level of significance. The 12 soybean genotypes were categorized as small-seeded (BARC-8, BARC-9, Hutcheson and MD86-5785), medium-seeded (Nakasennari, S90-1056, Suzuyataka and Ware), or large-seeded (Enrei, V71-370 and V81-1603), based on seed size. The seed size in small-seeded group varied from 124 to 138 mg seed^{-1}, in medium-seeded group varied from 149 to 171 mg seed^{-1} and in large-seeded group varied from 177 to 218 mg seed^{-1}. The means of various minerals from the three seed size groups were compared using Analysis of Variance.

RESULTS AND DISCUSSION

In general, the soybean genotypes did not influence the mineral composition of tofu, the only significant effect of genotypes was on the content of zinc in the tofu. The Zn content in tofu varied from 53 (For Hutcheson genotype) to 69 (For MD86-5785 genotype) with a mean of 62 mg kg^{-1} (Table 1). Locations significantly affected the contents of P, B, Zn and Mn (Table 2).

Phosphorus content varied from 0.6 (For Alabama location) to 0.7 (For Maryland location) with a mean of 0.7 percent. Boron content varied from 15.7 (For Maryland location) to 26.5 (For Alabama location) with a mean of 19.7 mg kg^{-1}. In the case of zinc, the content varied from 57.8 (For Alabama location) to 65.6 (For Virginia location) with a mean of 62.3 mg kg^{-1}. Manganese content varied from 18.9 (For Maryland location) to 61.4 (For Alabama location) with a mean of 42.9 mg kg^{-1}. Significant differences in tofu due to years and locations were also observed by Helms *et al*. [10].

In order to explain effects of growing locations, we studied temperature and rainfall at the three locations. The average maximum temperatures during growing season (May to October) were 83.4, 82.7, 85.5 F at Alabama, Maryland and Virginia locations, respectively. The average minimum temperatures during growing season (May to October) were 62.0, 59.3 and 63.0 F at Alabama, Maryland and Virginia locations, respectively. The means of average temperatures during growing season (May to October) were 72.7, 71.0 and 74.3 F at Alabama, Maryland and Virginia locations, respectively. These data suggest that lower maximum, minimum and average temperatures during growing season may be conducive to increased contents of P, B and Mn. On the other hand, higher maximum, minimum and average temperatures during

Table 1: Composition of tofu made from 12 genotypes grown at three locations in USA during 1995

	(%)								(mg kg^{-1})					
Genotype	Protein	Oil	Ash	S	P	K	Mg	Ca	B	Zn	Mn	Fe	Cu	Al
BARC-8	55.0	15.8	4.24	0.43	0.70	1.87	0.28	0.31	24.0	68.0	38.3	174	16.7	455
BARC-9	58.9	11.3	4.06	0.44	0.77	1.80	0.26	0.31	28.7	69.3	40.3	146	17.0	76
Enrei	53.3	20.3	3.90	0.39	0.72	1.73	0.27	0.26	19.3	64.7	48.3	153	14.7	73
Hutcheson	52.2	24.0	3.66	0.40	0.62	1.65	0.24	0.21	17.0	52.7	40.3	222	13.7	140
MD86-5785	55.1	19.8	3.88	0.42	0.67	1.75	0.24	0.25	20.0	68.0	46.7	177	15.7	117
Nakasennari	53.1	20.2	4.21	0.39	0.70	1.91	0.27	0.25	20.3	63.0	41.0	148	15.3	96
S90-056	52.5	22.4	3.69	0.39	0.67	1.67	0.23	0.23	13.5	67.0	38.0	285	14.0	163
Suzuyutaka	52.4	23.0	3.57	0.38	0.65	1.63	0.23	0.19	19.3	48.7	33.3	143	13.3	84
V71-370	51.7	21.3	3.98	0.40	0.72	1.75	0.29	0.26	17.7	66.3	47.0	149	16.0	118
V81-1603	53.3	20.4	3.87	0.41	0.64	1.78	0.23	0.22	17.7	61.7	41.0	201	16.0	236
Ware	50.6	20.3	4.02	0.42	0.66	1.81	0.27	0.25	21.0	59.7	55.3	228	16.0	246
York	51.6	22.9	3.82	0.37	0.62	1.68	0.28	0.25	15.3	60.3	44.0	283	15.7	450
Mean	53.4	20.1	3.92	0.40	0.68	1.76	0.26	0.25	19.7	62.3	42.9	190	15.4	188
LSD (0.05)	ns	4.6	ns	ns	ns	ns	ns	ns	ns	10.4	ns	ns	ns	ns

Table 2: Growing location effects on minerals in tofu made from 12 genotypes grown at three locations in USA during 1995

	(%)								(mg kg^{-1})					
Location	Protein	Oil	Ash	S	P	K	Mg	Ca	B	Zn	Mn	Fe	Cu	Al
Alabama	51.5	21.3	4.1	0.40	0.72	1.85	0.28	0.27	26.5	57.8	61.4	198	15.9	283
Maryland	53.7	19.3	3.8	0.40	0.73	1.70	0.26	0.24	15.7	63.2	18.9	189	14.9	185
Virginia	54.7	19.8	3.8	0.41	0.59	1.73	0.24	0.24	17.3	65.6	50.1	182	15.3	106
Mean	53.4	20.1	3.92	0.40	0.68	1.76	0.26	0.25	19.7	62.3	42.9	190	15.4	188
LSD (0.05)	23.3	ns	ns	ns	0.06	ns	ns	ns	4.1	5.2	8.6	ns	ns	ns

Table 3: Correlation coefficients between mineral composition and protein and oil in tofu made from 12 soybean genotypes grown at three locations in USA during 1995

Minerals	Protein	Oil
Sulfur	0.44**	-0.53**
Phosphorus	-0.14	-0.38*
Potassium	-0.34*	-0.25
Magnesium	-0.44**	-0.17
Calcium	0.16	-0.62**
Boron	-0.12	-0.34*
Zinc	0.46**	-0.68**
Manganese	-0.21	0.13
Iron	-0.26	0.19
Copper	0.00	0.08
Aluminum	-0.07	-0.05

*, **Correlation coefficient significantly different from zero at 5 and 1% level, respectively

growing season were conducive to increased contents of Zn. The total precipitation, during growing season (May to October), were 4.4, 3.3 and 4.1 inches at Alabama, Maryland and Virginia locations, respectively indicating that rainfall amounts may not affect the contents of P, B, Mn and Zn given that Alabama and Virginia locations had higher rainfall amounts which did not correspond to higher contents of these minerals. It is also possible that differences in concentrations of various minerals in the soils couples with differential absorption may also be responsible for differences in mineral composition of tofu. We did not study this aspect of tofu quality.

The correlation analysis (Table 3) indicated that contents of S and Zn were positively correlated to protein content of tofu whereas contents of K and Mg exhibited negative correlation with protein content of tofu. The contents of S and Zn were negatively correlated to oil content of tofu. Although, contents of P and Ca did not exhibit any relationship with protein contents, they exhibited negative correlations with oil contents.

The size of soybean seed did not affect the mineral contents of tofu (Table 4) except for the content of S in which case small and large seeded soybean seeds resulted in higher contents as compared to medium seeded soybean genotypes. Therefore, the common conception among soybean processors that large seeds

Table 4: Effects of seed size on composition of tofu made from 12 soybean genotypes grown at three location in USA during 1995

	(%)								(mg kg^{-1})					
Genotype	Protein	Oil	Ash	S	P	K	Mg	Ca	B	Zn	Mn	Fe	Cu	Al
Small	55.3	17.7	4.0	0.42	0.69	1.77	0.26	0.27	22.4	64.5	41.4	179	15.8	197
Medium	52.0	21.7	3.9	0.39	0.66	1.75	0.26	0.23	18.2	59.2	42.6	213	14.9	211
Large	52.8	20.7	3.9	0.40	0.69	1.76	0.26	0.25	18.2	64.2	45.4	167	15.6	142
Mean	53.4	20.1	3.92	0.40	0.68	1.76	0.26	0.25	19.7	62.3	42.9	190	15.4	188
LSD (0.05)	0.2	0.2	ns	0.02	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

make better tofu [6] may not be applicable in the case of soybean tofu.

A comparison of mineral composition of tofu produced in our studies with that of standard reference [8] indicated the existence of considerable differences. The contents of P, K, Mg and Ca, as a percentage seed dry weight, were 0.68 and 0.97, 1.76 and 1.21, 0.26 and 0.30 and 0.25 and 0.35, respectively for tofu in our studies and that from standard reference. Additionally, contents of Zn, Mn, Fe and Cu, as mg kg^{-1}, were 62.3 and 80.0, 44.0 and 60.5, 190 and 536 and 15.4 and 19.3, respectively for tofu in our studies and that from standard reference. However, both sets of tofu data are based on limited data points: ours are based on data are from one year and only three locations in the southern United States whereas the standard reference values are based on up to four data points indicating a need for further evaluations of mineral composition of tofu.

An issue of importance might be the relationship of minerals in tofu and their relationship to the recommended Dietary Reference Intakes (DRI). Based on the mineral contents in our studies, averaged over three locations with non-significant location effects, one serving of tofu (100 g) is expected to provide approximately 270 mg of Ca, 2 mg of Cu, 2 mg of Fe and 26 mg of Mg. The DRI values for human adults (Both males and females) for Ca, Cu, Fe and Mg are 1200 to1300 mg day^{-1}, 700 to 900 μg day^{-1}, 8 to 18 mg day^{-1} and 240 to 420 mg day^{-1}, respectively [11]. With regards to the contents of minerals when location effects were significant (Mn and Zn), the tofu produced from soybean produced in Alabama is expected to provide 0.1 mg Mn and 0.1 mg Zn per 100 g of tofu. The corresponding values were 0.02 and 0.1 mg for tofu produced in Maryland and 0.1 and 0.1 mg for tofu produced in Virginia. These data indicate that amount of tofu consumed to meet the DRIs, may need to be adjusted to supply adequate amounts of minerals like Mn where the content was significantly lower in tofu produced from soybean grown at a specific location such as Maryland for the content of Mn.

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