Physicochemical Properties and Tofu Quality of Soybean Cultivar Proto[†]

Chiun-Chuan Roger Wang[‡] and Sam Kow-Ching Chang*[,§]

Department of Food and Nutrition, Providence University, Taichung 43309, Taiwan, Republic of China, and Department of Food and Nutrition and Department of Cereal Science, North Dakota State University, Fargo, North Dakota 58105

The objective of this study was to investigate the physicochemical properties and tofu quality of Proto soybean grown at two different lots. The bean size, proximate chemical composition, weight of seed coat, total carbohydrate and nonstarchy polysaccharides (NSP), 11S/7S protein ratio, total and free cysteine, and amino acid patterns of the beans were determined. Tofu was made according to a laboratory method that employed calcium sulfate as a protein coagulant. The yield, texture profile, color, and NSP content of tofu were determined. Proto soybean produced tofu with excellent yields and good tofu characteristics. The two samples differed in size but did not differ in the physicochemical properties and in the yield and firmness of tofu. The sulfur-containing amino acids retained in tofu were only 40–50% of that in the raw soybean.

Keywords: *Proto soybean; physicochemical properties; tofu quality*

INTRODUCTION

Tofu is a soybean protein gel-like product and has been widely consumed in the Orient for more than 2000 years. For most Americans, tofu is receiving attention because it is low in calories and is cholesterol-free. A typical soft tofu is characterized by a bland taste and fine texture with an 84–90% moisture content (Kohyama et al., 1993).

Tofu manufacturers desire soybeans that are uniform in size and that provide a high yield and quality product. Yield and quality are affected by several factors, such as variety or cultivar (Skurray et al., 1980; Wang et al., 1983), soybean growth environment (Wang et al., 1983), and tofu-processing methods (Wang et al., 1983; Beddows and Wong, 1987a–c; Shen et al., 1991). Soybean varieties differ in chemical components, including proteins, lipids, and minerals, that may influence yield and quality of tofu (Skurray et al., 1980; Wang et al., 1983; Lim et al., 1990; Sun and Breene, 1991; Shen et al., 1991; Schaefer and Love, 1992).

Processing factors, which affect the quality of tofu, include soaking time and temperature, grinding temperature, soy milk heating rate, stirring speed, type and concentration of coagulant, method of adding coagulant to soy milk, and the weight and time of press (Lu et al., 1980; Tsai et al., 1981; Wang and Hesseltine, 1982; Beddows and Wong, 1987a–c; Sun and Breene, 1991). Beddows and Wong (1987a) reported the water/bean ratio in the range of 11–12:1 had maximum yield, but the ratio of 10:1 gave the best quality of tofu. Beddows and Wong also (1987b) noted that a faster heating rate produced better tofu quality due to more protein being retained in the tofu. Saio (1979) reported a higher stirring speed during soy milk heating produced tofu with a firmer texture. The scanning electron microscopic (SEM) and transmission electron microscopic (TEM) images of tofu showed a stronger stirring produced a denser network of tofu structure (Saio, 1979).

The textural characteristics are the important determinants for consumption. Protein content in soybean and soy milk affects tofu texture significantly. Wang et al. (1983) and Shen et al. (1991) reported that varieties higher in protein content produced firmer and more springy tofu texture. Soybean storage proteins, the ratios of 7S and 11S, differed among varieties. Tofu made from 11S protein was significantly harder than that from 7S protein (Saio et al., 1969). The 11S tofu also had greater cohesiveness and elasticity than the 7S tofu (Saio, 1979). The larger protein molecule (11S) had more sulfhydryl–disulfide interchange reaction during heat aggregation, resulting in a larger protein network, which showed a harder texture (Saio, 1979). The ratio of 11S/7S soybean protein affects the textural properties of tofu (Saio et al., 1969, 1974, 1979; Saio and Watanabe, 1978; Skurray et al., 1980).

Phytic acid can bind both protein and calcium to produce a colloidal precipitate, which results in a softer tofu during processing (Saio, 1979; Prattley and Stanley, 1982). However, Lim et al. (1990) worked on nine varieties of soybeans and found no correlations between phosphorus content and hardness of tofu, although they found that smaller size soybeans had higher phytic acid content. Schaefer and Love (1992) found that phytic acid and copper ion contents were significantly correlated with tofu texture. Moreover, coagulant type and concentration play a significant role in the textural characteristics of tofu (Lu et al., 1980; Tsai et al., 1981). The texture of tofu is affected by various protein coagulants. Calcium sulfate, magnesium sulfate, calcium chloride, and glucono-δ-lactone are widely used for manufacturing different types of tofu (Tsai et al., 1981; deMan et al., 1986; Shen et al., 1991; Sun and Breene, 1991; Skurray et al., 1980).

In industrial practice, large size soybeans are preferred for tofu making. The total amount of the seed coat in the small soybeans is higher than in the large

* Author to whom correspondence should be addressed [telephone (701) 231-7485; fax (701) 231-7485 or (701) 231-7723; e-mail Chang@plains.nodak.edu].

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[‡] Providence University.

[§] North Dakota State University.

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soybeans. The higher amount of the seed coat in the small soybeans is considered by the tofu industry to have a negative effect on the yield and the quality of tofu (personal communications with the tofu industries). However, the influence of the size of soybean on the yield and quality of tofu has not been reported in the scientific literature. Proto soybean is a new food soybean cultivar grown in the upper northern plains of the United States and has not been studied with respect to physicochemcial properties and tofu quality.

The objectives of this study were to investigate the physicochemical properties and tofu quality of small and large size Proto soybean and to investigate the effect of the added seed coat to the large Proto soybean on tofu quality.

MATERIALS AND METHODS

Samples. Large (LS) and small seeds (SS) of the Proto cultivar soybean grown in two lots in 1992 were obtained from the Sinner Brothers and Bresnahan Co. (Casselton, ND). The pedigrees of Proto cultivar included Chippewa 64, Provar, Pridesoy II, and experimental lines developed at the University of Minnesota—St. Paul (Orf et al., 1991). After harvest, beans were stored at 5 °C until tofu processing. Antifoaming agent (containing 89.5% glycerol fatty acid ester, 8% lecithin, 2% $MgCO_3$, and 0.5% silicon resin) was obtained from Kaoh Co. (Wakayama, Japan). Food grade coagulant (a mixture of $CaSO_4{\cdot}2H_2O$ and natural nigari) was obtained from Taiwan Salt Workers (Tainan, Taiwan).

Characteristics of Soybean Size and Seed Coat. The number of soybean seeds per 100 g was counted. Two hundred grams of large and small soybeans was soaked in tap water for 8 h. The seed coat was peeled by hand, freeze-dried over 24 h, and vacuum-dried (<25 mmHg) for 5 h at 100 °C to obtain a moisture-free sample. The percentage of seed coat in the large and small seeds was calculated on a dry weight basis.

Proximate Analysis of Soybean and Tofu. Tofu was freeze-dried. The soybean and freeze-dried tofu were ground to pass a 60-mesh screen. Moisture, proteins, lipids, and ash were determined according to AOAC Methods (AOAC, 1990) 925.10, 955.04, 945.16, and 942.05, respectively.

Phytic Acid Determination. Phytic acid in soybean was extracted according to the method of Wang et al. (1988). Phosphorus in the extract (total) and soluble fraction was determined according to the method of Fiske and Subbarow (1925). The difference between total and soluble phosphorus was insoluble phosphorus (Bartlett, 1959) from phytic acid.

Soy Milk Preparation and Solids Content Measurement. Three different types of soybean samples, i.e., large size soybean, small size soybean, and large size soybean plus 0.5% seed coat (LSP), were used for tofu study. The large size soybean containing 0.5% seed coat, which was peeled from small soybeans, was used to determine the effect of seed coat on tofu yield and quality. The reason for selecting 0.5% was that the seed coat of the small soybean was 0.5% (w/w) greater than that of the large seeds. Five batches of soybeans (600 g each batch) for each bean type were washed and soaked in tap water at 15−18 °C for 8 h. Hydrated soybeans were drained and ground with 5.4 L of tap water in a high-speed grinder (Chan Shen Machinery Co., Taoyuan, Taiwan), which was equipped with an automatic centrifugal filter to separate the residue and soy milk.

To increase the solid extraction from the soybean, the residue from each grinding was stirred (washed) in 5.4 L of water for 5 min and filtered to obtain filtrate. The filtrate was used to replace water for the grinding of the second batch of soybean. In this study, the soy milk (approximately 5 L) from the first batch was not used for tofu making. The reason for not using the first batch was that soybeans are usually ground with the washed water in the tofu industry to increase yield. The total volume and degree Brix of soy milk were measured. The degree Brix of the soy milk was determined using a refractometer (AutoAbbe, Model 10500, Buffalo, NY) at 20 °C. The solid content of soy milk was estimated from a standard curve, which was constructed previously in our laboratory using solid content of various concentrations of soy milk determined by oven-drying versus degree Brix (Johnson and Wilson, 1984).

In a similar manner, the residues from the second, third, and fourth batches were washed, and the filtrates were used to grind the third, fourth, and fifth batches, respectively. The soy milk from the second to the fifth batches was used to prepare tofu. Therefore, tofu making was replicated four times for each soybean type.

Tofu Making. Four and a half liters of soy milk was used for one mold (268 × 268 × 70 mm) of tofu preparation. After adding antifoaming agent (0.07% of the raw soybean weight) was added, soy milk was cooked to boiling with gentle stirring and kept for 5 min at approximately 95 °C. After cooling to 88 °C, the soy milk was poured into a container containing 50 mL of suspended coagulant (3% of the raw bean weight). The coagulated soy milk was transferred into the wooden mold immediately and pressed with a 12-lb steel plate for 40 min. After pressing, the cloth was removed, and the tofu was allowed to stand for 5 min before the weight was measured. The yield of tofu was expressed as the weight of tofu on the basis of weight of soybean contributing to 4.5 L of soy milk.

$$\text{yield of tofu} = \text{wt of tofu}/540 \text{ g of soybean}$$

$$540 \text{ g of soybean} = 600 \text{ g}\left(\frac{4.5 \text{ L, soy milk taken for tofu processing}}{5.0 \text{ L, total volume of soy milk from 600 g}}\right)$$

Textural Analysis. The texture profile of tofu was measured using an Instron Universal Testing Machine (Model 1000, Instron Co., Canton, MA) equipped with a 500-kg weight beam. A 5-kg load cell was used with a cross-head control at 20 mm/min. A cylindrical plunger 5 cm in diameter was used to compress the tofu. The chart paper speed was 20 mm/min. A piece of tofu (1.5 cm height with 5 cm diameter) was cut for texture profile analysis. Six tofu cakes from each batch were measured by compressing twice to 25% of the original height of each cake. Hardness, fracturability, elasticity, and cohesiveness were calculated using the Instron Texture Profile analysis curve as described by Wang and Hesseltine (1982) and Bourne (1968).

Color Analysis. The Gardner Lab Model XL-23 colorimeter (Gardner Lab Inc., Bethesda, MD) was used to measure the surface color of tofu. The instrument was standardized using a standard white tile ($L = 91.94$, $a = -1.03$, $b = 1.14$).

Total Nonstarchy Polysaccharide (NSP) and Total Carbohydrate (CHO). A 200-mg sample of defatted soybean flour or defatted dried tofu was analyzed for total NSP (Englyst and Cummings, 1988). The sample was dispersed and hydrolyzed by α-amylase and pullulanase. The residue from enzymic digestion was followed by acid hydrolysis. The sample for total CHO determination was prepared without enzymic digestion. The neutral sugars in the hydrolyzed solution were reduced and derivatized to alditol acetates, which were quantitated using a Hewlett-Packard (Model 5890 Series II, Avondale, PA) gas chromatograph. Standard sugars, L-rhamnose, L-arabinose, D-xylose, D-mannose, D-galactose, and D-glucose, were used. D-Allose was used as an internal standard. The uronic acid was determined according to the procedure of Scott (1979).

Total Cystine/Cysteine and Free Cysteine. The methods for determining for total cystine/cysteine and free cysteine (−SH group) were those of Felker and Waines (1978) and Chang et al. (1982). A 150−200-mg sample was finely ground with double-distilled water and diluted to 10 mL. Total cystine/cysteine in the sample was analyzed in 9 M urea after reduction with $NaBH_4$. Free cysteine was analyzed without reduction. Samples with or without reduction were reacted with dithionitrobenzoic acid (DTNB). Absorbance at 412 nm was taken approximately 20 min after DTNB was added. A standard curve was constructed using glutathione.

Table 1. Characteristics of Raw Soybeans of the Proto Cultivar[a]

seed size	no. of seeds per 100 g of beans	dimensions: length, mm	width, mm	thickness, mm	% seed coat in soybeans
large	501a	7.9a	7.0a	6.0a	5.9a
small	622b	7.0b	6.4b	5.3b	6.4b

[a] Means with different letters in the same column differ significantly ($p < 0.05$).

Extraction and Determination of 7S and 11S Proteins. The method for extraction and determination of 7S and 11S was modified from those of Nagano et al. (1992) and Arrese et al. (1991). Soybean flour and freeze-dried tofu were defatted and extracted in water at pH 7.5. The slurry was extracted for 1 h and centrifuged at 9000*g* for 30 min. The protein content of the extracts was determined by using the biuret method. The extract was diluted to contain 2 mg/mL. A phosphate buffer containing sodium dodecyl sulfate (SDS) was added to the protein extracts, and the mixture was heated for 2 min in boiling water. A 50-μL portion of the protein extract was used for polyacrylamide gel electrophoresis (PAGE), using the procedure of Laemmli (1970). For 7S and 11S protein quantification, gel was scanned with a densitometric scanner (Model GS300, Hoefer Scientific Instruments Co., San Francisco, CA). The ratio of 7S to 11S protein was calculated from the sum of the area of their subunits.

Amino Acid Composition. Amino acids were determined using acid hydrolysis, followed by precolumn phenyl isothiocyanate (PITC) derivatization and reversed-phase high-performance liquid chromatography (RP-HPLC) (Bidlingmeyer et al., 1984; Chang et al., 1989).

Statistical Analysis. One-way analysis of variance of the data was performed using a Statistical Analysis System package (SAS, 1990). When differences were observed, the least significant difference (lsd) test was used to analyze the significance of the treatment ($p < 0.05$).

RESULTS AND DISCUSSION

Characteristics of Soybean. The number of seeds in 100 g of soybean and percentage (w/w) seed coat of the soybean are listed in Table 1. The large size soybean ranged from 490 to 512 seeds/100 g, and the small size soybean ranged from 609 to 630 seeds/100 g. The length, width, and thickness of the large size Proto soybean were greater than those of the small size Proto soybean. The percentage of seed coat of the small soybean was 0.5% higher ($p < 0.05$) than the large size soybean (Table 1). Because the seed coat weights differed significantly between the two soybean samples, seed coats separated from the small seeds were added to the large bean for tofu testing to determine its effect on tofu properties.

Proximate Analysis. The protein content (Table 2) of the large and small size soybeans was lower than the protein content of 45.6% reported in the original cultivar registration document (Orf et al., 1991). The protein content of Proto soybean was greater than that of tofu soybean cultivars Vinton, Amsoy 71, Corsoy, and Hardin (Lim et al., 1990; Sun and Breene, 1991; Schaefer and Love, 1992). No significant differences ($p > 0.05$) were found in lipid, ash, and phytic acid contents for both sizes of soybeans. In the chemical composition of tofu, there were no differences ($p > 0.05$) in protein, lipid, and ash contents between the two sizes of soybean.

Solid Content and Yield. The solid content of soy milk and yield of tofu are shown in Figure 1. No significant difference ($p > 0.05$) in solid content of soy milk was observed among large size soybean, small size soybean, and LSP soy milk. In the tofu industry, the

Table 2. Proximate Composition of Proto Soybean and Tofu[a,b]

size of soybean	protein (%)	lipid (%)	ash (%)	CHO[c] (%)	phytic acid (mg/g)
		Raw Soybean			
large	43.60a	18.06a	5.43a	33.91	12.73a
small	42.77b	18.61a	5.52a	33.10	12.05a
		Tofu			
large	5.56a	2.46a	0.43a	2.29	ND[e]
small	5.21a	2.78a	0.51a	2.26	ND
LSP[d]	5.27a	2.65a	0.53a	1.99	ND

[a] Means with different letters in the same column differ significantly ($p < 0.05$). [b] The proximate composition of soybean was calculated on the basis of dry matter. [c] CHO% = 100% − (protein + oil + ash)%. [d] LSP, large size soybean plus 0.5% seed coat. [e] ND, not determined.

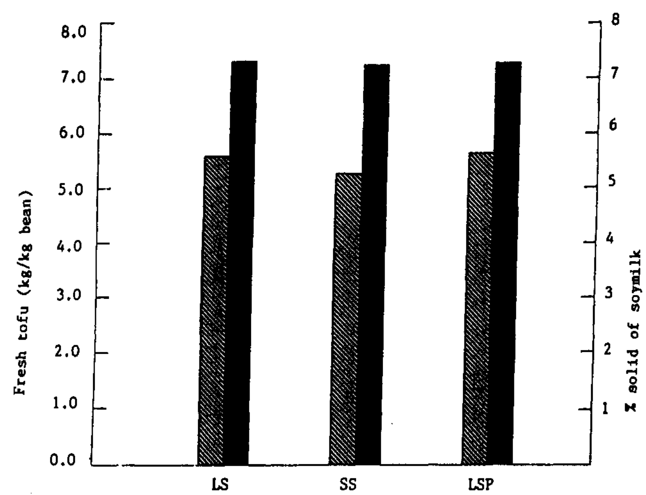

Figure 1. Percent solids of soy milk and fresh tofu yield from large (LS) and small size soybean (SS) and the large size soybean plus 0.5% seed coat (LSP): (slashed bar) yield; (black bar) % solid.

residues from the first grinding are normally washed with water two to three times to extract all of the proteins from the soybeans to increase yield. In this study, the degree Brix of the filtrate was approximately 2. The degree Brix of the soy milk increased from approximately 7.0 to 7.2 to 8.6 to 8.8 when the filtrate was used to replace water for grinding the soybeans. Using a refractometer to measure the concentration of solid is rapid and is good for quality control in tofu processing.

In the industrial manufacturing of tofu, large size soybeans are preferred for making tofu. However, our study showed no significant difference in the yield of tofu between the large and small size soybeans of the same cultivar (Figure 1). Tofu produced from the large size soybeans containing peeled seed coat did not differ significantly ($p > 0.05$) from the large and small soybean. Shen et al. (1991) reported that solid content of the soy milk was related to the yield of tofu. The solid contents of the soy milk derived from the three soybean samples were similar (approximately 7.3%).

The tofu yield of Proto was greater than the values reported for other soybeans that were processed using calcium sulfate as a coagulant. The fresh tofu yield of Proto (approximately 5.5−5.6 g/g of bean) was greater than the 3.5−4.6 g/g yield range of five soybean cultivars reported by Sun and Breene (1991), the 4.4−5.3 g/g yield of nine soybean cultivars reported by Lim et al. (1990), and the 4.4−4.8 g/g yield of six Japanese/Chinese cultivars (Taira, 1990).

Table 3. Texture Characteristics of Tofu Made from Small and Large Size Soybeans and the Large Size Soybean plus 0.5% Seed Coat[a]

size of soybean	hardness (g)	fracturability (g)	elasticity (cm)	cohesiveness
large	2551a	511a	0.85a	0.335a
small	2509a	455b	0.68b	0.328a
LSP[b]	2549a	494a	0.78ab	0.346a

[a] Means with different letters in the same column differ significantly ($p < 0.05$). [b] LSP, large size soybean plus 0.5% seed coat.

Table 4. Color Characteristics and Subjective Test of Tofu from Small and Large Size Soybeans and the Large Size Soybean plus 0.5% Seed Coat[a]

size of soybean	Hunter *Lab*			subjective test	
	L	*a*	*b*	color	texture
large	86.41a	0.42a	15.79a	creamy white	soft and smooth
small	85.93a	0.36a	16.25a	creamy white	soft and smooth
LSP[b]	86.25a	0.45a	16.80a	creamy white	soft and smooth

[a] Means with different letters in the same column differ significantly ($p < 0.05$). [b] LSP, large size soybean plus 0.5% seed coat.

The high yield of Proto soybean may be partly related to its high protein content. Proto soybean had a higher protein content than the five soybean cultivars (protein ranging from 36 to 41%) reported by Sun and Breene (1991). Lim et al. (1990) and Shen et al. (1991) reported positive correlations of protein content of nine varieties of soybeans with fresh yield of tofu made with GDL or calcium sulfate. However, protein was not the single factor to affect yield. Calcium, ash, phytic acid, and lipid contents also are related to tofu yield (Lim et al., 1990; Shen et al., 1991). It is difficult to compare the yield of various soybean cultivars reported in the literature since various processing methods were used.

Texture Characteristics. Tofu made from Proto soybean had a cohesive and smooth texture, which is one of the desirable characteristics. The small size soybean had less ($p > 0.05$) fracturability than the large size soybean and LSP tofu (Table 3). Small size soybean tofu had less elasticity than large size soybean tofu. However, there were no significant differences in hardness and cohesiveness of tofu between the two sizes of Proto soybean (Table 3). The hardness of tofu was affected by the types of coagulants and protein content of soy milk (Wang and Hesseltine, 1982; deMan et al., 1986; Shen et al., 1991). The hardness of Proto tofu produced in this study approached that of a commercial regular-style tofu and was greater than a Kinugoshi-style tofu produced by the House Foods and Yamauchi Inc. (Los Angeles, CA).

Color Characteristics. White or creamy white color is a desirable tofu characteristics. All of the tofu produced from this research showed a creamy white color. The *L*, *a*, and *b* values among large and small size soybeans and LSP tofu did not differ (Table 4). The *L* value ranged from 85.93 to 86.41 (Table 4), indicating that the whiteness of tofu was close to the standard white tile ($L = 91.94$).

Total NSP and CHO. The NSP is composed of cell wall polysaccharides (the main ingredient of dietary fiber), including cellulose, hemicellulose, and pectic substances, which may cross-link with calcium to affect the texture of tofu (Shen et al., 1991). Total CHO includes total NSP, sugars, and starches in the soybean. It is known that soybean has very little starch. The major carbohydrates in soybean are NSP and sugars. No literature has reported the relationship between NSP and texture profiles. The results (Table 5) showed that a slightly higher ($p < 0.05$) content of NSP was found in small size Proto soybean than in large size Proto soybean. However, the total NSP and total CHO of tofu did not differ between these two sizes of soybean. The NSP in tofu was the polysaccharide fraction that was soluble in water and was extracted into soy milk during grinding. The NSP might have interacted with protein molecules or been trapped in the protein network in the final tofu product.

Total and Free Available Cysteine and 11S/7S Ratio. Lee and Rha (1978) and Utsumi and Kinsella (1985) reported that the soybean curd strength was related to soybean intermolecular binding force, including hydrogen bond, disulfide bond, and hydrophobic interaction. The small size Proto soybean had higher total available cysteine than large size Proto soybean (Table 6). However, free cysteine contents were similar. Taira and Taira (1972) studied the bean protein components in 30 Japanese cultivars of food soybeans grown in three locations and found the 11S/7S protein ratio ranged from 0.7 to 1.4, with most beans in the range of 0.8−1.2. The 11S/7S ratio of large size Proto soybean was higher than that of the Japanese cultivars.

Saio (1979) reported the 11S/7S ratio in soy milk strongly affected the textural properties of tofu. He found 11S protein Ca tofu was harder than 7S Ca tofu because the free sulfhydryl group in 11S tofu was higher than that in 7S tofu. Taira (1990) reported the protein to lipid ratio affected the hardness of tofu, but the 11S/7S ratio did not correlate with the yield and hardness of tofu. Figure 2 shows a typical SDS−PAGE electro-

Table 5. Total Nonstarchy Polysaccharide (NSP) and Total Carbohydrate (CHO) in Proto Soybean and Tofu[a]

size of soybean	neutral sugars[b]						uronic acid	total NSP
	Rha	Ara	Xyl	Man	Gal	Glu		
			Nonstarchy Polysaccharides					
raw								
large	0.40	2.86	1.50	2.92	5.17	4.88	2.24	19.48a
small	0.48	3.08	1.67	3.08	4.96	4.98	2.40	20.63b
tofu								
large	0.07	0.39	0.09	0.52	1.38	2.36	0.26	5.07a
small	0.09	0.29	0.07	0.52	1.11	2.53	0.27	4.88a
			Total Carbohydrate					
tofu								
large	0.11	0.89	0.36	1.41	1.96	2.66	0.26	7.65a
small	0.10	0.84	0.36	1.55	2.02	2.88	0.27	8.01a

[a] Data are g/100 g sample on a dry weight basis. Means with different letters in the same column differ significantly ($p < 0.05$). [b] Rha, rhamnose; Ara, arabinose; Xyl, xylose; Man, mannose; Gal, galactose; Glu, glucose.

Table 6. Total Cystine/Cysteine, Free Cysteine, and 11S/7S Ratio of Proto Soybean[a]

seed size	total cystine/cysteine (g/100 g of protein)	free cysteine (g/100 g of protein)	11S (%)	7S (%)	11S/7S (%)
large	1.93a	0.18a	50.59a	33.28a	1.52a
small	2.39b	0.19a	49.11a	35.33a	1.39a

[a] Means with different letters in the same column differ significantly ($p < 0.05$).

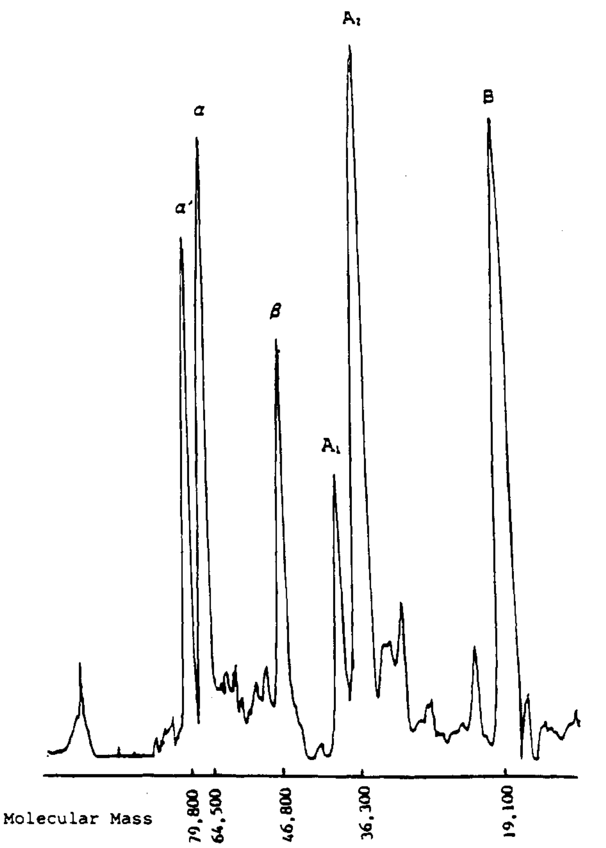

Figure 2. Densitometric scanning of 7S and 11S globulin protein subunits of the large size Proto soybean. 7S subunits include α, α′, and β subunits. 11S subunits include A and B subunits.

phoregram of Proto soybean proteins. There were no differences in 11S/7S ratio and free cysteine content between the large and small size soybean (Table 6).

Amino Acid Analysis. Amino acid composition analysis (Table 7) showed no difference ($p > 0.05$) between the large and small size Proto soybean in both raw bean and tofu. However, aspartic acid, serine, phenylalanine, methionine, and total available cysteine and cystine decreased, and glutamic acid increased after tofu processing. The cystine/cysteine content might have been reduced because the tofu gels did not include the cystine-rich Bowman–Birk trypsin inhibitors (small 2S proteins) in soybean (Odani and Ikenaka, 1973). The sulfur amino acids, methionine and cystine/cysteine, are the limiting essential amino acids of soybean proteins. Therefore, tofu processing might decrease the protein quality slightly due to the decrease in the sulfur amino acids. This is the first study to report the effect of tofu making on the amino acid composition of soybeans.

Conclusion. This study showed that tofu with excellent yield and quality can be made from Proto soybean. No difference existed between two sizes of Proto in yield, color, appearance, and amino acid composition. This study suggested that the size of the same soybean cultivar does not affect the quality and yield of tofu.

Table 7. Amino Acid Patterns of Soybean and Tofu[a]

amino acid	amino acids (g/100 g of protein)			
	soybean		tofu	
	large seeds	small seeds	large seeds	small seeds
Ala	4.5	4.3	5.7	5.5
Arg	7.0	7.2	7.2	7.6
Asp	10.2	11.0	4.7	4.5
Cys	1.9	2.4	0.6	0.7
Glu	18.6	19.2	23.5	22.4
Gly	4.1	4.3	5.0	5.4
His	2.4	2.6	2.8	2.6
Ile	4.3	4.5	5.1	5.0
Leu	7.2	7.9	8.7	8.4
Lys	6.3	6.5	6.9	7.6
Met	1.5	1.6	1.0	0.8
Phe	5.0	5.1	3.6	3.5
Pro	5.4	5.6	6.2	6.6
Ser	5.1	5.4	3.5	3.7
Thr	4.2	3.8	4.0	3.9
Tyr	2.6	2.8	2.5	2.1
Val	6.0	6.2	5.4	6.2
total	96.3	100.2	96.4	96.5

[a] All amino acids were determined according to the HPLC procedure of Bidlingmeyer et al. (1984) except total cystine/cysteine (Cys), which was determined according to the colorimetric method of Felker and Waines (1978).

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