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Chemical Compositions and Physicochemical Properties of the Fiber-Rich Materials Prepared from Shoyu Mash Residue

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Fiber-rich materials including desalted shoyu mash residue (briefly referred as desalted mash residue, DMR), alcohol-insoluble solid (AIS), and water-insoluble solid (WIS) were prepared from shoyu mash residue, which is a filtration cake obtained during the isolation of shoyu by press filtration of fermented matrix in the final process. The DMR, AIS, and WIS contain rich dietary fiber of 52.4, 61.5, and 54.7 wt %, respectively. The DMR, AIS, and WIS all have significantly lower bulk densities, and higher water-holding capacities, oil-holding capacities, swelling abilities, and cation-exchange capacities than the control cellulose. These results indicated that the said fiber-rich materials prepared in this study all have the desired physicochemical properties for being used as satisfactory sources of dietary fibers or low-calorie bulk ingredients in food applications requiring oil and moisture retention. Furthermore, the said fiber-rich materials also have high contents of isoflavones, mainly daidzein and genistein, which are considered as the most bioavailable phytoestrogens, with a total amount of about 1200−1480 μmol/100 g (equal to daidzein of ca. 3040−3759 μg/g, or genistein of 3240−3996 μg/g). The results revealed that the said fiber-rich materials might be a potent fiber source for health foods.

KEYWORDS: Soy sauce; shoyu mash residue; chemical composition; dietary fiber; physicochemical properties; isoflavones

INTRODUCTION

It is well known that dietary fiber, the indigestible cell wall component of plant materials, plays an important role in reducing the risk of cardiovascular disease (*1*), hyperlipidemia (*2*), obesity (*3*), gastrointestinal disorders (*4*), certain cancers (*5*), and lowering postprandial serum glucose level (*6*). The increasing awareness of the health benefits of fiber has led to various dietary recommendations, which suggest that we increase our fiber intake substantially (*7*).

The average fiber intake in Europe has been reported to be in the range of 16−21 g/day (*8*). Highly variable values (12−24 g/day) are found in Japan (*9*), while the daily intake in the United States is relatively lower (12−13 g/day) (*10*). To reach the recommendations of 20−35 g of dietary fiber per day, or 10−12 g/1000 kcal, it would be necessary to change dietary habits by increasing the intake of fruits, vegetables, and whole grain cereal products (*11*). Another possibility is the production of fiber-enriched foods by incorporating dietary fiber sources such as cereal bran, pulps, or pomace, which are now mainly used as feeds, fertilizers, or fuels.

Many processed food byproducts produced a large amount of waste residues that were used as animal feeds or directly discarded to cause environmental pollution problem. Among the processed food byproducts, a lot of them are rich in dietary fibers. Many studies have shown that agricultural byproducts could be the potential sources of dietary fibers. For example, wheat straw, soy hulls, oat hulls, peanut and almond skins, corn stalks and cobs, spent brewer's grains, and waste portions of fruits and vegetables processed in large quantities can be considered as useful fiber ingredients (*12*).

Shoyu (soy sauce) made from soybean is a main seasoning in the Asian area. Shoyu is made from defatted soybeans and wheat of the ratio of 1:1. The steamed defatted soybean flakes and the baked wheat grains were mixed and inoculated with *Aspergillus oryzae* and/or *Aspergillus sojae*, followed by cultivation at 25−40 °C for about 3 days. The culture was then mixed with brine (ca. 23% NaCl) to make a mash containing 16−18% of NaCl to be fermented for about 6 months to 1 year. After fermention, the mash is subjected to press filtration to isolate shoyu. The mash residue obtained as a filtration cake is mainly used for animal feeds (*13*). However, they can be used as a good source of dietary fiber because of their high fiber content. Moreover, soy-based foods are a rich source of isoflavones, a major group of phytoestrogens that resemble endogenous estrogen (17-β-estrodiol), that have been reported to be implicating potential health benefits related to age-related and hormone-dependent diseases, including cancer, menopausal symptoms, cardiovascular disease, and osteoporosis (*14*−*20*). The isoflavones are a type of polyphenol and are reported to possess antioxidant properties (*21*−*23*). The presence of isoflavones in fiber-rich materials will benefit the consumer's health more than just the dietary fibers.

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In this study, we succeed in developing new fiber-rich materials from shoyu mash residue. The physicochemical properties and general compositions of these new fiber-rich foodstuffs as well as the in vitro studies of hypoglycemic and antioxidative effects were discussed. In addition, the isoflavone contents of the said fiber-rich materials were also determined.

MATERIALS AND METHODS

Preparation of Lyophilized Desalted Mash Residue (DMR). Shoyu mash residue (hereafter briefly referred to as mash residue) was provided by a local soy sauce manufacturing company near Taipei. The mash residue was suspended in 10-fold of water (w/v) with occasional mixing to remove the residual sodium chloride, and then filtered through a stainless 40-mesh filter. After the residue was washed three times, the insoluble fraction was lyophilized. The lyophilized mash residue was ground into homogeneous powders using a Waring blender and stored in a vacuum container until use.

Preparation of Alcohol-Insoluble Solid (AIS) and Water-Insoluble Solid (WIS). AIS was prepared according to the method of Thomas et al. (*24*) with a slight modification. The desalted mash residue powder was homogenized in 20-fold (w/v) of 85% (v/v) boiling ethyl alcohol for 50 min with a Waring blender. The mixture was filtered and the retention was air-dried at 35 °C to obtain the AIS. WIS was prepared by suspending the desalted mash residue powder in 20-fold (w/v) of cold distilled water and homogenized at high speed using a Waring blender for 1 min. The insoluble fraction was collected and air-dried at 35 °C to obtain the WIS.

Analysis of General Composition. Moisture was determined by drying to a constant weight at 105 °C. The ash content was determined according to AOAC method (*25*). The crude lipid content was determined by extracting the sample with petroleum ether with a Soxhlet apparatus. The protein content was determined by the micro-Kjeldahl method (*25*). All analyses were carried out in triplicate.

Determination of Soluble and Insoluble Dietary Fibers (SDF and IDF). The determinations of SDF and IDF were carried out according to the AOAC method (*25*). They were determined by using a fiber assay kit (Sigma Chemical Co., St. Louis, MO). Briefly, about 1 g of sample was digested by α-amylase, protease, and amyloglucosidase, in that order, followed by filtration to obtain the supernatant and the insoluble fraction. The supernatant was then precipitated with 95% alcohol to precipitate the SDF and quantified by drying overnight at 105 °C. The insoluble fraction was washed with 78% and 95% alcohol solutions and acetone, respectively, followed by drying overnight at 105 °C to obtain the IDF. The dietary fiber contents were corrected for residual protein, ash, and blank. The total dietary fiber was indicated as the sum of IDF and SDF.

Physicochemical Properties of Fibers. The bulk density (g/mL), swelling property, and cation-exchange capacity (meq/Kg) of the insoluble fiber-rich materials were determined according to the methods described by Ralet et al. (*26*). The water-holding capacities (WHCs) and oil-holding capacities (OHCs) were determined as described by Chau (*27*) with a slight modification. Briefly, WHC and OHC were, respectively, determined by mixing tested samples with 20-fold (w/v) distilled water for 24 h or with 10-fold (w/v) soybean oil for 6 h, and then centrifuged at 2200*g* for 1 h. Subsequently, free water or free oil was drawn off the top of the mixture with a pipet and weighed in a preweighed bottle.

Effect of Fibers on Adsorption of Glucose. According to the method of Ou et al. (*6*), 1 g of sample was suspended in 100 mL of glucose solution (concentration ranging from 10 to 200 mM) at 37 °C for 6 h, and then centrifuged at 3500*g* for 20 min. The glucose content in the supernatant was determined. The glucose-bound capacity (mmol/g) of the fiber-rich materials was calculated according to eq 1:

$$\text{glucose-bound capacity (mmol/g)} = (\text{glucose concentration of original solution} - \text{glucose concentration when the adsorption reached equilibrium}) \times \text{volume (L) of solution} \div \text{weight (g) of tested sample} \quad (1)$$

Effect of Fiber-Rich Materials on the Activity of α-Amylase. The assay was performed according to the method of Ou et al. (*6*) with a little modification. One gram of each fiber-rich material was well mixed with 100 mL of 1% (w/v) starch solution in a 250 mL flask. One gram of commercial α-amylase was added into the mixture and incubated at 37 °C for exactly 30 min, followed by terminating the amylolytic reaction by heating the mixture in boiling water for 10 min. After the mixture was centrifuged at 1800*g* for 30 min, the glucose content of the supernatant was determined and expressed as reducing power of glucose equivalents. The inhibitory activity (%) of tested sample on α-amylase was defined as the percent decrease in the glucose production rate (μmol/h) over the control, wherein the data obtained without the addition of fiber were used as the control.

Determination of Isoflavones in the Fiber-Rich Materials. The procedure of Wang and Murphy (*28*) with some modification was employed for extracting isoflavones from the tested fiber-rich materials. Briefly, 2 g of finely ground fiber-sample was mixed with 50 mL of 80% methanol followed by stirring with a magnetic stirrer for 2 h at room temperature, and filtered through a Whatman no. 42 filter paper. The filtrate was evaporated to almost dryness with a vacuum rotary evaporator below 40 °C. The dried matter was redissolved in 5 mL of 80% methanol and transferred to a 10-mL volumetric flask. The sample container was rinsed with another 3 mL of 80% methanol and combined with former solution. An additional 1 mL of 5000 ppm methanolic benzoic acid solution was added as the internal standard, and the final volume was made up to 10 mL with 80% methanol. The sample solution was filtered through a 0.45 μm nylon syringe filter (Micron Separation Inc., Westborough, MA) prior to HPLC analysis. A linear gradient of mobile phase was composed of 0.1% glacial acetic acid in H_2O (solvent A) and 0.1% glacial acetic acid in acetonitrile (solvent B). After the injection of 20 μL of sample, solvent B was increased from 10% to 30% over 60 min, then increased to 90% within the next 3 min, and finally returned to the initial 10% within 2 min and held at this percentage for 12 min to equilibrate the system. The flow rate of mobile phase was 1.0 mL/min. The HPLC system consisted of Thermo Separation Products ConstaMetric 3200 and 3500 gradient pumps equipped with a Thermo Separation products SpectroMonitor 3200 digital UV detector. Peak areas were integrated using the SISC Chromatography Data Station version 3.0. A reversed-phase analytical column (Phenomenex Luna C18(2), 250 × 4 mm, 5 μm) was used to carry out the separation. The detection wavelength was set at 254 nm.

Measurement of Free Radical Scavenging Activity of the Fiber-Rich Materials. One gram of dried, finely ground sample was added into a flask containing 20 mL of 80% methanol. The mixture was homogenized for 1 h at room temperature and filtered through a Whatman no. 42 filter paper. Afterward, the filtrate was centrifuged for 10 min at 1800*g*, and the supernatant was collected and dried under vacuum. The dried material was redissolved in 100% methanol and diluted to a series of concentrations (from 0.2 to 2.0 mg/mL). The free-radical scavenging activity was evaluated by measuring the scavenging activity of methanol extract of the fiber-rich materials on the 2,2-diphenyl-1-picrylhydrazil (DPPH). The DPPH assay was performed as described by Espin et al. (*29*). Briefly, 1 mL of sample (from 0.2 to 2.0 mg/mL) or blank (methanol) was mixed with 4 mL of 90 μM DPPH solution and incubated at room temperature for 1 h, followed by measuring the absorbance at 515 nm. The α-tocopherol was used as a positive control.

Statistical Analysis. Data were expressed as mean ± SD. The difference between two groups was tested by using the Student's *t*-test, and ANOVA (Ducan's test) was tested within more than two groups. Statistical analysis was performed by using SAS version 8.2.

RESULTS AND DISCUSSION

Yields and General Compositions of DMR, WIS, and AIS. As shown in **Table 1**, the yields of AIS and WIS obtained were 86.0 and 93.7 g/100 g, respectively. The yields indicated that the shoyu mash residue was a good source for preparing the fiber-rich materials to be used as food additives or as fiber supplements.

Table 1. Yields of AIS and WIS Fractions Prepared from Desalted Shoyu Mash Residue

fiber-rich material	yield (g/100 g dry basis)
AIS	86.0 ± 1.70[a]
WIS	93.7 ± 1.50

[a] Mean ± standard deviation of triplicate.

Table 2. General Compositions of the DMR and Its AIS and WIS Fractions

component	composition (g/100 g)[a]		
	DMR	AIS fraction	WIS fraction
moisture	6.2 ± 0.1 a[d]	5.5 ± 0.06 c	5.8 ± 0.05 b
crude protein	23.8 ± 0.9 a	23.6 ± 1.4 a	24.4 ± 1.6 a
crude fat	9.2 ± 0.7 a	3.4 ± 0.5 c	7.2 ± 0.5 b
total dietary fiber (TDF)[b]	52.4 ± 1.5 c	61.5 ± 1.8 a	54.7 ± 1.8 b
insoluble dietary fiber (IDF)	50.8 ± 1.3 b	59.6 ± 1.7 a	52.6 ± 1.5 b
soluble dietary fiber (SDF)	1.6 ± 0.02 c	1.9 ± 0.02 b	2.1 ± 0.03 a
ash	2.2 ± 0.02 a	2.2 ± 0.02 a	2.1 ± 0.02 b
carbohydrate[c]	6.2 ± 0.19 a	3.8 ± 0.02 c	5.8 ± 0.04 b

[a] Mean ± standard deviation of triplicate. [b] Fiber contents were corrected for protein and ash. [c] Carbohydrate was defined as the residue excluding moisture, protein, fat, TDF, and ash, and was calculated by difference (=100 – moisture – protein – lipid – TDF – ash). [d] Data with different letters in the same row are significantly different ($p < 0.05$).

The general compositions of the DMR, AIS, and WIS were shown in **Table 2**. The DMR possessed high content of dietary fiber, 52.4 g/100 g, mainly the insoluble dietary fiber, 50.8 g/100 g. The total dietary fiber contents of the DMR, the AIS, and the WIS were all higher than those fiber sources such as citrus (25−70%), cranberry (6−8%), pear (10%), prune (16−57%), raisin (6−8%), and raspberry (2−5%) (*30*−*32*).

It was reported that the dietary fiber contents of various fiber-rich fractions were greatly affected by the preparation methods (*27*). The dietary fiber contents of the DMR, the AIS, and the WIS in this study were 52.4%, 61.5%, and 54.7%, respectively (**Table 2**). These dietary fiber contents were higher than most of the other fiber-rich products prepared from some other agricultural byproducts, such as citrus, mango, and quince. The yields of AIS were reported to be 45.9−75% for citrus (*33*), 30.7−49.7% for mango (*34*), and 27.8−37.5% for quince (*24*), that were quite lower than the AIS prepared from shoyu mash residue. In considering both the yields and the dietary fiber contents, the fiber-rich materials prepared in this study should be the potent sources of dietary fiber to be used in the food industry. Gourgue et al. (*34*) reported that the dietary fiber prepared from mango byproducts had a much higher dietary content of about 71−76%, however, the preparation method thereof was much more complicated than the preparation of the fiber-rich materials of this study. According to the method of Gorgue et al. (*34*), the AIS with 71−76% dietary fiber was obtained by extensive washing with aqueous ethanol solutions. In detail, the fibrous pulp waste (FPW) was immersed for 10 min in boiling 95% ethanol under manual stirring, followed by filtration on a G2 sintered glass filter, washed with70% ethanol until the eluate became colorless, and dried by sequential rinsing with absolute ethanol, acetone, and ether, and finally vacuum-dried at 40 °C for 24 h. In contrast, the DMR of this study is prepared just by simple washing away the salt and drying. Besides, the used washing water containing NaCl can be recycled for the preparation of shoyu mash in the next operation.

Physicochemical Properties of Fibers. Table 3 indicated that the bulk density of the three dietary-rich materials was significantly lower than that of cellulose. Their WHCs were similar to those fiber-rich products obtained from some fruit byproducts (7−13 mL/g) disclosed by Grigelmo-Miguek et al. (*35*, *36*). The OHCs of the three dietary fiber-rich materials were 5.36 mL/g for the mash residue, 5.08 mL/g for the AIS, and 3.95 mL/g for the WIS, significantly higher than the value of 3.10 mL/g for cellulose (**Table 3**). The OHC is closely dependent on the bulk density of the material. The particles with lower bulk density usually have greater surface area, and accordingly have greater capacity to adsorb and/or bind the lipid components (*27*, *37*, *38*). The swelling properties of the three dietary fiber-rich materials were significantly higher than that of cellulose. Polysaccharides are hydrophilic molecules with numerous free hydroxyl groups and can adsorb more water through hydrogen bonds. Insoluble fibers can adsorb water in the manner like a sponge. They form a hydrophilic matrix in which water is entrapped, wherein the water fills the interstices of the polysaccharide quasi-crystalline to cause a considerable swelling. The spongelike, water-holding matrix was reported to be able to improve the conditions of fecal bulk and consistency so as to prevent the constipation (*39*). As shown in **Table 3**, the cation-exchange capacities of the three dietary fiber-rich materials (300−670 mequiv/kg) were significantly higher than that of cellulose (30 mequiv/kg). The high cation-exchange capacity of fiber could entrap, destabilize, and disintegrate a lipid emulsion, leading to the decrease of diffusion and absorption of lipids (*40*). The differences in the physicochemical properties among the three dietary fiber-rich materials might be attributed to their different chemical and physical structures as reported by Chau and Huang (*27*). As compared to the control cellulose, the significant higher cation-exchange capacities as well as the WHC and OHC of the three fiber-rich materials of this study might be attributed to their lower bulk density and higher swelling ability. The higher swelling abilities obviously mean that they have higher porosity and larger surface area, and the higher porosity is in agreement with their lower bulk density.

Table 3. Physicochemical Properties of the Dietary Fiber-Rich Materials Prepared from Shoyu Mash Residue[a]

fiber sample	bulk density (g/mL)	WHC (mL/g)	OHC (mL/g)	swelling (mL/g)	cation-exchange capacity (mequiv/kg)
cellulose	0.40 a	4.30 c	3.10 d	5.02 c	30 d
DMR	0.20 c	10.85 a	5.36 a	11.0 a	519 a
AIS	0.18 cd	8.39 b	5.08 b	9.39 b	300 c
WIS	0.27 b	8.07 b	3.95 c	9.07 b	467 b

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

Table 4. Glucose Bound (mmol/g) by Dietary Fiber in Solutions of Different Glucose Concentrations

	glucose concentration			
	200 (mmol/L)	100 (mmol/L)[a]	50 (mmol/L)	10 (mmol/L)
cellulose	17.9 ± 0.2 d	8.3 ± 0.1 d	3.6 ± 0.1 d	trace
DMR	22.3 ± 1.4 a	13.0 ± 0.2 a	5.1 ± 0.1 a	1.1 ± 0.1 a
AIS	19.1 ± 0.2 b	10.2 ± 0.2 b	4.3 ± 0.3 b	0.8 ± 0.1 b
WIS	18.6 ± 0.2 c	9.9 ± 0.1 c	3.9 ± 0.1 bc	0.9 ± 0.1 b

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

Effects of Dietary Fiber on the Adsorption of Glucose and the Activity of α-Amylase. Table 4 showed the adsorptions of glucose by the various dietary fiber-rich materials in a series

Table 5. Effect of the Dietary Fiber-Rich Materials on α-Amylase Activity

fiber sample	reducing sugar produced (μmol/h/g)	inhibitory activity[a] (%)
control	409 ± 6.2 a	
DMR	272 ± 3.5 d	33.5 ± 0.9 a
AIS	363 ± 5.2 b	11.2 ± 0.3 c
WIS	345 ± 4.3 c	15.6 ± 0.5 b

[a] The inhibitory activity (%) against amylase was defined as the percent decrease in the glucose production rate over the control (without fiber, 409 μmol/h/g). Data with different letters in the same column are significantly different ($p < 0.05$).

Table 6. Isoflavone Contents[a] of the Dietary Fiber-Rich Materials (μmol/100 g)

fiber sample	daidzin	daidzein	genistin	genistein	total isoflavone
DMR	7.1	422 a	ND	1003 b	1432 b
AIS	ND[b]	228 c	ND	978 c	1206 c
WIS	ND	407 b	ND	1067 a	1474 a

[a] Data with different letters in the same column are significantly different ($p < 0.05$). [b] ND = not detected.

of different concentrations of glucose solutions. The results indicated that the amounts of glucose bound by the dietary fiber materials of this study were all higher than that of cellulose. As shown in **Table 5**, the reducing sugar production rate by α-amylase was significantly inhibited by the DMR, AIS, and WIS. Their inhibition rates of α-amylase activity were 33.5%, 11.2%, and 15.6%, in that order. The inhibition rate of α-amylase activity was defined as the percent decrease in glucose production rate over that of the control (without the dietary fiber). It revealed that the activity of α-amylase was differently affected by various insoluble fibers at different levels. Dietary fiber can be adsorbed by starch and thus hinder the hydrolysis of starch by α-amylase (*41*). It was reported that the inhibition of α-amylase activity by various insoluble fibers depended on the fiber concentration, the presence of inhibitors in the fibers matrix, the capsulation of starch and enzyme by fibers, and the direct adsorption of α-amylase onto fiber (*6*, *34*). Moron et al. reported that α-amylase inhibition by fibrous residues was positively related to the fiber contents and seemed to be in accordance with the adsorption mechanism (*42*). The abilities of the dietary fiber-rich materials to adsorb glucose and reduce α-amylase activity indicated that they could be the candidates as functional dietary supplements for decreasing the rate of glucose absorption as well as the concentration of postprandial serum glucose.

Isoflavone Contents of the DMR, AIS, and WIS. As shown in **Table 6**, the total isoflavone contents of the DMR, AIS, and WIS were 1432, 1206, and 1474 μmol/100 g, respectively. They contain much more isoflavone than soy products such as tofu (195 μmol/100 g) (*43*). Furthermore, the isoflavones in the DMR, AIS, and WIS were mainly daidzein and genistein, as shown in **Figure 1**, that were reported as the most bioavailable isoflavones in soybean foods (*44*). Therefore, they are good sources of isoflavones as well as dietary fibers. The processing of soybean affects the nutritional content of the soy food products significantly. It was suggested that enzymatic hydrolysis, heating, and fermentation significantly altered the distributions of free and bound isoflavones (*29*). Recent studies suggested that isoflavones in their glycosylated forms were much less effectively absorbed than those in aglycone forms (*44*). The

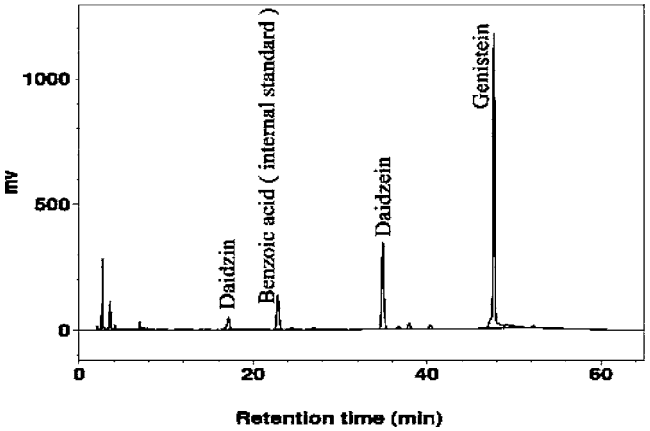

Figure 1. HPLC chromatogram of the extract from the desalted shoyu mash residue.

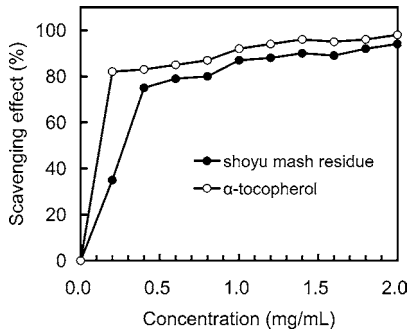

Figure 2. Effect of methanol extract from desalted shoyu mash residue on the DPPH free radical scavenging.

isoflavones that remained in the DMR were mainly the more bioavailable forms, daidzein and genistein. Accordingly, they would be a potential food supplement for both the dietary fiber and the phytoestrogens.

Effect of Methanol Extract of Mash Residue on the Scavenging of DPPH Free Radicals. The results of **Figure 2** revealed that the methanol extract from shoyu mash residue showed a remarkable scavenging effect on DDPH free radicals. The effect was comparable to that of α-tocopherol. Free radicals involved in the process of lipid peroxidation are considered to play a cardinal role in numerous chronic diseases and are implicated in the aging process (*22*, *23*). Therefore, the dietary fiber-rich materials might also be helpful in the prevention of the so-called degenerative diseases and aging process.

Conclusions. Recently, numerous literature reported that sufficient consumption of dietary fibers could promote beneficial physiological functions including blood cholesterol and glucose attenuation, laxation, and reduced risk of coronary heart disease, colon cancer, and obesity. On the other hand, the nonsteroidal phytoestrogenic isoflavones in soybeans have been reported to have potential protective or preventive properties against several major chronic diseases, including cardiovascular diseases, cancers, and osteoporosis. The desalted shoyu mash residue of this study can be easily prepared by simple washing with water to remove the salt therein. The desalted shoyu residue thus prepared contains a relatively high content of dietary fiber of 52.4%. It also contains a rich amount of the most bioavailable isoflavone, daidzein (422 μmol/100 g or 1072 μg/g) and genistein (1003 μmol/100 g or 2708 μg/g). Consequently, the desalted shoyu residue would be a potentially beneficial dietary fiber source to be used as a health food ingredient in the food

industry. Furthermore, the washed saline water could be recycled for use in the making of shoyu mash so as to reduce the cost and prevent environmental pollution.

ABBREVATIONS USED

DMR, desalted mash residue; AIS, alcohol-insoluble solids; WIS, water-insoluble solids; TDF, total dietary fiber; IDF, insoluble dietary fiber; SDF, soluble dietary fiber; WHC, water-holding capacity; OHC, oil-holding capacity; DPPH, 2,2-diphenyl-1-picrylhydrazil; ANOVA, analysis of variance.

LITERATURE CITED

(1) Anderson, J. W.; Allgood, L. D.; Turner, J.; Oeltgen, P. R.; Daggy, B. P. Effect of psylluim on glucose and serum lipid responses in men with type 2 diabetes and hypercholesterolemia. *Am. J. Clin. Nutr*. **1999**, *70*, 466−473.

(2) Hughes, J. S. Potential contribution of dry bean dietary fiber to health. *Food Technol.* **1991**, *9*, 122−126.

(3) Rolls, B. J.; Bell, E. A.; Castellanos, V. H.; Chow, M.; Pelkman, C. L.; Thorwart, M. L. Energy density but not fat content of foods affected energy intake in lean and obese woman. *Am. J. Clin. Nutr*. **1999**, *69*, 863−871.

(4) Deng, G. Y.; Liu, Y. W.; He, G. Z.; Jiang, Z. M. Dietary fiber protection on intestinal barrier function. *Asian J. Surg.* **2000**, *23*, 90−96.

(5) Slavin, J. L.; Jacobs, D.; Marquart, L.; Wiemer, K. The role of whole grains in disease prevention. *J. Am. Diet. Assoc*. **2001**, *101*, 780−785.

(6) Ou, S.; Kowk, K. C.; Li, Y. In vitro study of possible role of dietary fiber in lowering postprandial serum glucose. *J. Agric. Food Chem.* **2001**, *49*, 1026−1029.

(7) Lee, S. C.; Prosky, L. Perspectives on complex carbohydrate definition. *Cereal Foods World* **1996**, *41*, 88−89.

(8) Cummings, J. H.; Frolich, W. Dietary fibre intakes in Europe. In *Metabolic and physiological aspects of dietary fibre in food*; Cummings, J. H., Frolich, W., Eds.; Commission of the European Communities: Luxembourg, 1993; p 1.

(9) Mori, B.; Nakaji, S.; Sugawara, K.; Ohta, M.; Iwane, S.; Munakata, A.; Yoshida, Y.; Ohi, G. Proposal for recommended level of dietary fiber intake in Japan. *Nutr. Res.* **1996**, *16*, 53−60.

(10) Ganji, V.; Betts, N. Fat, cholesterol, fiber and sodium intakes of US population: evaluation of diets reported in 1987-88 nationwide food consumption survey. *Eur. J. Clin. Nutr.* **1995**, *49*, 915−920.

(11) Food and Nutrition Board (FNB), Institute of Medicine (IOM). Dietary reference intakes for energy, carbohydrates, fiber, fat, fatty acids, cholestrol, protein, and amino acids (macronutrients); National Academy of Science, Washington, DC, 2002.

(12) McNeillie, A.; Bieser, J. Hydrogen peroxide uses for the year 2000. *Food Process.* **1993**, *54*, 59−65.

(13) Bauchat, L. R. *Food and Beverage Mycology*; AVI Publishing Co., Inc.: Westport, CT, 1978; p 232.

(14) Tham, D. M.; Gardner, C. D.; Haskell, W. L. Potential health benefits of dietary phytoestrogens: a review of clinical, epidemiological, and mechanistic evidence. *J. Clin. Endocrinol. Metab.* **1998**, *83*, 2223−2235.

(15) Setchell, K. D. R.; Cassidy, A. Dietary isoflavones: biological effects and relevance for human health. *J. Nutr*. **1999**, *129*, 748S−767S.

(16) Messina, M. J. Legumes and soybeans: overview of their nutritional profiles and health effects. *Am. J. Clin. Nutr*. **1999**, *70*, 439S−450S.

(17) Jacobsen, B. K.; Knutsen, S. F.; Fraser, G. E. Does high soy milk intake reduce prostate cancer incidence, the adventist health study (United States). *Cancer Causes Control* **1998**, *9*, 553−557.

(18) Kulling, S. E.; Lehmann, L.; Metzler, M. Oxidative metabolism and genotoxic potential of major isoflavone phytoestrogens. *J. Chromatogr., B* **2002**, *83*, 113−118.

(19) Messina, M. Soyfoods and soybean phyto-estrogens (isoflavones) as possible alternatives to hormone replacement therapy (HRT). *Eur. J. Cancer* **2000**, *36*, S71−S72.

(20) Adlercreutz, H. Phytoestrogen and breast cancer. *J. Steroid Biochem. Mol. Biol.* **2002**, *83*, 113−118.

(21) Arora, A.; Nair, M. G.; Strasburg, G. M. Antioxidant activities of isoflavone and their biological metabolites in a liposomal system. *Arch. Biochem. Biophys.* **1998**, *356*, 133−141.

(22) Anthony, M. S.; Clarkson, T. B.; Williams, J. K Effects of soy isoflavones on atherosclerosis: Potential mechanisms. *Am. J. Clin. Nutr*. **1998**, *68*, 1390S−1393S.

(23) Yamakoshi, J.; Piskula, M. K.; Izumi, T.; Tobe, K.; Saito, M.; Katapka, S.; Obata, A.; Kikuchi, M. Isoflavone aglycone-rich extract without soy protein attenuates atherosclerosis development in cholesterol-fed rabbits. *J. Nutr*. **2000**, *130*, 1887−1893.

(24) Thomas, M.; Crepeau, M. J.; Rumpunen, K.; Thibault, J. F. Dietary fiber and cell-wall polysaccharides in the fruits of Japanese quince (*Chaenomeles japonica*). *Lebensm.-Wiss. Technol.* **2000**, *33*, 124−131.

(25) AOAC. *Official Methods of Analysis*, 13th ed.; Association of Official Analytical Chemists: Washington, DC, 1980.

(26) Ralet, M. C.; Della Valle, G.; Thibault, J. F. Raw and extruded fiber from pea hulls. Part I: composition and physicochemical properties. *Carbohydr. Polym.* **1993**, *20*, 17−23.

(27) Chau, C. F.; Huang, Y. L. Characterization of passion fruit seed fibres—a potential fibre source. *Food Chem.* **2004**, *85*, 189−194.

(28) Wang, H.; Murphy, P. A. Mass balance study of isoflavones during soybean processing. *J. Agric. Food Chem.* **1996**, *44*, 2377−2383.

(29) Espin, J. C.; Soler-Rivas, C.; Wichers, H. J. Characterization of the total free radical scavenger capacity of vegetable oils and oil fractions using 2,2-diphenyl-1-picrylhydrazil radical. *J. Agric. Food Chem.* **2000**, *48*, 648−656.

(30) Przybyla, A. E. Formulating fiber into food. *Food Eng.* **1988**, *60*, 77−88.

(31) Ranhotra, G. S.; Gelroth, J. A.; Glaser, B. K. Energy value of resistant starch. *J. Food Sci.* **1996**, *61*, 453−455.

(32) Duxbury, D. D. Stabilized flax: high-fiber protein source. *Food Process.* **1993**, *54*, 93.

(33) Ting, S. V. Alcohol-insoluble constituents of juice vesicles of citrus fruit. *J. Food Sci.* **1970**, *35*, 757−761.

(34) Gourgue, C. M. P.; Champ, M. M. J.; Lozano, Y.; Delort-Laval, J. Dietary fibre from mango byproducts: characterization and hypoglycemic effects determined by in vitro methods. *J. Agric. Food Chem.* **1992**, *40*, 1864−1868.

(35) Grigelmo-Miguek, M.; Martin-Belloso, O. Characterization of dietary fiber from orange juice extraction. *Food Res. Int.* **1999**, *31*, 355−361

(36) Grigelmo-Miguek, M.; Martin-Belloso, O. Comparison of dietary fiber from byproducts of processing fruits and greens and from cereals. *Lebensm.-Wiss. Technol.* **1999**, *32*, 503−508.

(37) Gordon, D. T. Functional properties vs. physiological action of total dietary fiber. *Cereal Foods World* **1989**, *34*, 517−525.

(38) Bao, B.; Chang, K. C. Carrot pulp chemical composition, color, and water-holding capacity as affected by blanching. *J. Food Sci.* **1994**, *59*, 1159−1161.

(39) Oakenfull, D. Physiochemical properties of dietary fiber: overview. In *Handbook of Dietary Fiber*; Cho, S. S., Dreher, M. L., Eds.; Marcel Dekker: New York, 2001; pp 195−206.

(40) Furda, I. Interaction of dietary fiber with lipids mechanistic theories and their limitations. In *New Developments in Dietary Fiber*; Furda, I., Brine, C. J., Eds.; Plenum Press: New York, 1990; pp 67−82.

(41) Annison, G.; Topping, D. L. Nutritional role of resistant starch: chemical structure vs physiological function. *Annu. Rev. Nutr.* **1994**, *14*, 297−320.
(42) Moron, D.; Melito, C.; Tovar, J. Effect of indigestible residue from foodstuffs on trypsin and pancreative -amylase activity in vitro. *J. Sci. Food Agric.* **1989**, *47*, 171−179.
(43) Kao, F. J.; Su, N. W.; Lee, M. H. Effect of water-to-bean ratio on the contents and compositions of isoflavones in tofu. *J. Agric. Food Chem.* **2004**, *52*, 2277−2281.
(44) Izumi, T.; Piskula, M. K.; Osawa, S.; Obata, A.; Tobe, K.; Saito, M.; Kataoka, S.; Kubota, Y.; Kikuchi, M. Soy isoflavone aglycones are absorbed faster and in higher amounts than their glucosides in humans. *J. Nutr.* **2000**, *130*, 1695−1699.

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