ORIGINAL ARTICLE

Preparation and characterization of fine powdered whole soybean curd

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Junghee Shin. Preparation and characterization of fine powdered whole soybean curd. *JENB.*, Vol. 19, No. 4, pp.297-302, 2015

[Purpose] Efficacy and comparative characteristics of fine powdered whole soybean curd. **[Methods]** Ground dried soybean to a fine powder (700 mesh) containing bean components in its entirety, and then produced whole soybean curd. Analysed its nutritive components, bioactive substances, antioxidant activities and texture compared with pressed soybean curd. **[Results]** Compared with pressed soybean curd, the nutrients and isoflavone in whole soybean curd were slightly decreased, but antioxidant activities, dietary fibers and moisture content were increased. Also, the yield rate of the total process was improved 1.9 times. **[Conclusion]** Fine powdered whole bean curd has antioxidant effects, contains dietary fiber and possesses soft characteristics, hence has development potential in the diet market and as food for patients. **[Key words]** Whole soybean curd, texture, antioxidant

INTRODUCTION

According to the findings of a recent epidemiological investigation, the incidence of hormone-related disorders such as prostate cancer, breast cancer, osteoporosis, and cardiovascular diseases were significantly higher in Western societies, which have higher intake of meats and lower intake of soybeans compared with East Asians, who belong to the soybean food culture category. As a result, there is more interest in the intake of soybeans and in the bioactive compounds contained in soybeans [1]. It was found that the dietary fibers and phytochemical compounds contained in soybeans are responsible for their prophylactic effects [2,3]. Meanwhile, as our eating habits have changed from a traditional diet that obtains proteins from beans and processed beans to a meat-oriented, western-style dietary pattern, the incidence of metabolic diseases such as obesity, diabetes and hyperlipidemia are currently on the rise. Meat-oriented protein intake increases the intake of saturated fatty acids, which leads not only to various adult diseases and cancers, but also has an amplifying effect for the occurrence of obesity, cardiovascular diseases, colorectal cancer and prostate cancer due to the reduced intake of a variety of bioactive substances contained in beans [3]. Recently, consumers with meat-

oriented eating habits have become more interested in healthy food, manifested as a growing interest in vegetarian diets. Consumer interest in healthy food containing plenty of bioactive substances that prevent obesity and cardiovascular diseases in addition to enhancing immunity is increasing along with its consumption.

Although soybean curd has been established for a long time as an important protein food source for Koreans [4], the utilization and consumption of the food have been limited. Intake of soybean curd is primarily limited to side dishes such as roasting and stews due to its bland taste and hard texture. However, recently, as the soybean curd diet continues to gain popularity among young people, interest in the development of diverse soybean curd products is on the rise while breaking the concept of the food as a side dish. Soybean curd is a very good addition to the diet in that it is a low-calorie food with 80~90 kcal / 100 g, gives a feeling of fullness due to its high water content, has a higher digestive absorption rate than soybeans by 95% [3,5] and stimulates bowel movements due to its high dietary fiber content. During the conventional soybean curd manufacturing process [6,7], soybeans are soaked in about 10 times the amount of water for 10 hours to increase the extraction efficiency of proteins. The soybeans are then ground along with water, followed by steaming and

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filtering out bean-curd dregs. The resulting soybean milk is hardened by adding bittern. Because of the high amount of water used in the hardening process, physical pressure is applied for dehydration and shaping. When soybean curd is manufactured with this traditional pressing method, many soluble proteins are lost during the processes of long-soaking and pressing. Major bioactive compounds contained in the husk of soybeans such as isoflavones, dietary fibers, saponins and oligosaccharides are lost to the bean-curd dregs as well. Both the large nutritional loss and low yield of pressed soybean curd due to the removal of bean-curd dregs are factors that increase the manufacturing cost. Moreover, recently, the price of imported soybeans is half that of domestic soybeans, which makes the accessibility of soybean curd made of domestic soybeans to general consumers difficult. For this reason, a manufacturing process for whole soybean curd that includes all components of the typically discarded bean-curd dregs was developed [7,8]. However, due to the rough texture of the bean-curd dregs, it did not receive a positive response from consumers. As the technology for the micropulverization of raw soybeans to 700 mesh was recently popularized, whole soybean curd manufactured with finely powdered soybeans is now on the market. However, most of the research on soybean curd to date was by studies that compared the characteristics of pressed soybean curd after adding specific substances to plain soybean curd [3,5,9,10]. Research on whole soybean curd [7,8,11] focusing on the nutrients [7] and physical properties of fine powered whole bean curd [8] is limited. Therefore, the purpose of this study is to manufacture whole bean curd made of fine power and analyze it in terms of the yield rate, nutrients including dietary fibers, quality, bioactive compounds such as isoflavone and antioxidant activities for a comparison with pressed soybean curd. Additionally, the study aims to examine the potential for the development of soybean curd as diet food and for treatment.

METHODS

Materials for whole soybean curd and the manufacturing process

Experimental materials

In order to ensure the functionality and price-competitiveness of the resulting product, Daepung bean, which is a domestic species with high isoflavone content, low production cost and price-competitiveness compared to imported soybeans, was selected for use in the experiment. To improve the yield rate

Fig. 1. Procedure for whole soybean curd

while maintaining the soft flavor, whole soybean curd was manufactured using soybeans micropulverized to 700 mesh. During the whole soybean curd manufacturing process, natural bittern (prepared seawater magnesium chloride) and TG (trans glutaminase, Ajinomoto Korea Inc.), were added to the soybean milk as coagulants with concentrations up to 0.9% of the soybean milk to strengthen the resilience of the whole bean curd.

Manufacturing of whole soybean curd

The manufacturing process for whole soybean curd is as shown in Fig.1. The soybean curd samples were commissioned and manufactured by Jayeondleae, Inc. Raw soybeans were passed through a cutting machine to make fine powder to 700 mesh. The resulting Daepung bean powder was mixed with water to a concentration of 14°Bx and then heated for 30 minutes at 103°C to make warm soymilk. After a 2:1 mixture of MgCl₂ and Transglutaminase was added to the warm soymilk as a coagulant at a concentration of up to 0.9% of the total amount of the soybean milk, it was heated for 30 minutes at 85°C for stabilization, followed by packaging and sterilization for 30 minutes at 85°C.

The composition and quality characteristics of whole soybean curd

Component analysis

Nutritional components

Nutritional components were measured according to the methods described in the Food Code [12]. Water content was measured by heat drying under atmospheric pressure and indicated as a percentage. Crude fat, crude protein and crude

ash were analyzed by the Soxhlet extraction method, Kjeldahl method and 550°C direct ashing method, respectively. Carbohydrate content was determined after subtracting the total content (%) of water, crude protein, crude fat and crude ash based on the sample of 100%.

Isoflavone content

For the measurement of isoflavone content, the following method was repeated three times. Samples were extracted by adding 2 mL 0.1 N HCl and 10 mL acetonitrile to a 2 g sample, followed by stirring at room temperature for 2 hours. Then, after the extract was centrifuged at 3,400 rpm for 20 minutes, 8 mL supernatant was mixed with 10 mL 80% methanol, followed by stirring using a vortex mixer and filtration through a filter paper of 0.2 µm PTFE membrane for analysis with HPLC. Daidzein, genistein and glycitein, which were used as reference substances, were purchased from Sigma-Aldrich Com. (St. Louis, MO, USA).

Quality characteristics

Chromaticity

To evaluate the chromaticity of the whole soybean curd, the values of L (lightness), a (redness) and b (yellowness) were determined using a chromameter (CM-3500d, Minolta Co., Osaka, Japan). The measurement of chromaticity was repeated three times and the value was inserted into the following formula to obtain ΔE (color difference).

Reference white panel: L_s value was 97.75, a_s value was -0.38 and b_s value was 1.88

Texture

To examine the texture of whole soybean curd, it was cut into a predetermined size ($2 \times 2 \times 2$ cm) and then subjected to Texture profile analysis (TPA) using texture (TA/XT2, Stable Micro System, UK). The measurement conditions are as shown in Table 1. and the values of hardness, springiness, cohesiveness, adhesiveness and chewiness for the soybean curd were measured.

Table 1. Operating condition of texture profile analysis

Measurement	Operating conditions
Test type	Texture profile analysis
Pre-test speed	10 mm/s
Test speed	1 mm/s
Post test speed	1 mm/s
Distance	10 mm
Contact area	400 mm ²
Contact Force	5 g

Antioxidant activities

Total polyphenol content

To determine the total polyphenol content, 1 mL 2% Na₂CO₃ solution(w/v) was added to 1 mL of the methanol-extracted sample. After 3 minutes of sitting, 200 µl 50% Folin-Ciocalteu reagent (Sigma-Aldrich, St. Louis, MO, USA) was added, followed by vortexing and 30 minute incubation for reaction. After the incubation, the absorbance was measured using a spectrophotometer (Epoch Microplate Spectrophotometer, BioTek Instruments, Winooski, Vermont, USA) at 750 nm. Gallic acid (Sigma-Aldrich, St. Louis, MO, USA) was used as a reference substance for total polyphenol content and the absorbance was inserted into the formula obtained from the standard curve to determine the total polyphenol content of the sample.

Total flavonoid content

For total flavonoid content determination, 10 mL 90% diethyleneglycol was mixed with 0.2 mL of the methanol-extracted sample. 0.2 mL 4N NaOH was added, followed by incubation for reaction at 30°C for 5 minutes. After the reaction, the absorbance was measured using a spectrophotometer (Epoch Microplate Spectrophotometer, Biotek Instruments, Winooski, VT, USA) at 420nm. Rutin (Sigma Chemical Co. St. Louis, MO, USA) was used as a reference substance for total flavonoid content and the value of absorbance was inserted into the formula obtained from the standard curve to determine the total polyphenol content of the sample.

DPPH scavenging activity

To measure the DPPH scavenging activity, 80 mL 0.4 mM DPPH solution (Sigma Chemical Co. St. Louis, MO, USA) was mixed with 500 mL methanol, which was filtered through a filter paper (Toyo, no.5A) and stored in a cool, dark place. Methanol was added to 0.8 mL of the prepared DPPH solution, followed by stirring for 10 seconds. The amount of methanol was adjusted to bring the value of the absorbance after stirring to 0.95-0.99. Afterward, 0.2 mL methanol-extracted sample, 0.8 mL prepared DPPH solution and an appropriate amount of methanol were mixed, stirred vigorously for 10 seconds and allowed to sit for 10 minutes. The absorbance was then measured using a spectrophotometer (Epoch Microplate Spectrophotometer, BioTek Instruments, Winooski, Vermont, USA) at 517nm. Instead of the methanol-extracted sample, the same amount of methanol was used to measure the absorbance of the control group.

DPPH radical scavenging activity (%) =

$$\left(1 - \frac{\text{Absorbance of sample}}{\text{Absorbance of the control group}}\right) \times 100$$

ABTS scavenging activity

To measure ABTS scavenging activity, a radical stock solution was made by mixing the same amount of 7mM ABTS (2,2'-azino-bis-(3-ethylbenzothiazoline-6-sulphonic acid, Sigma Chemical Co. St. Louis, MO, USA) and 2.45mM potassium persulfate. The radical stock solution was diluted to bring the absorbance to 0.7 ± 0.02 when measured at 734nm with a spectrophotometer. 970 μ l radical stock solution was added to 50 μ l sample and the absorbance was measured at 734nm. Methanol was used for measurement of the absorbance of the control group.

ABTS radical scavenging activity (%) =

$$\left(1 - \frac{\text{Absorbance of sample}}{\text{Absorbance of the control group}}\right) \times 100$$

Statistical processing

All tests except for the measurement of general composition and sensory evaluation were measured in triplicate and all the experimental data were indicated as the mean $\pm$ standard deviation (SD). All statistical processes were performed using SAS version 9.3 (SAS Institute, Cary, NC, USA) with the significance level of $P < 0.05$. ANOVA (analysis of variance) was performed and Duncan's multiple range test was used for post verification if significance was observed.

RESULTS AND DISCUSSION

Component analysis

Yield rate and nutritional components

The yield rates of pressed soybean curd and whole soybean curd during the manufacturing process were as shown in Table 2. The yield rate of fine powdered whole soybean curd was 530%, which was a 1.9-fold increase from pressed soybean curd. The analysis of nutritional components revealed that the water content of whole soybean curd was high at 86.9% and the nutritional components were as shown in Table 3. Crude protein and crude fat were decreased in the whole soybean curd and carbohydrates including dietary fibers were increased by approximately two-fold. According to the analysis, the amount of protein in whole soybean curd was lower than in

Table 2. Comparison of yield for different soybean curds

Yield of soybean curd (%) ¹⁾	
Pressed soybean curd	280
Whole soybean curd	530

¹⁾ Yield of soybean curd(%) = weight of soybean curd product/weight of soybean (100g)

Table 3. Nutritional components of different soybean curds

	Moisture	Nutritional Components (%)			
		Carbohydrate	Crude protein	Crude fat	Crude ash
Pressed soybean curd	84.1	2.0	8.0	5.0	0.7
Whole soybean curd	86.9	4.2	5.5	2.5	0.7

Table 4. Isoflavone contents in different soybean curds

	Isoflavone contents (μ g/g)			
	Daidzein	Glycitein	Genistein	Total
Pressed soybean curd	53.9 ± 6.6^a	11.7 ± 1.2^a	221.5 ± 5.1^a	287.1
Whole soybean curd	44.7 ± 0.3^b	3.9 ± 0.01^b	170.0 ± 1.8^c	218.6

Values are mean $\pm$ SD.

Different letters within a column indicate significant differences ($p < 0.05$) at $\alpha = 0.05$ as determined by Duncan's multiple range test ($a > b > c$)

pressed soybean curd. However, considering that the yield rate of whole soybean curd was increased by 1.9-fold compared with pressed soybean curd, it is reasonable to assume that its nutritional components are not significantly inferior to those of pressed soybean curd. This result is in agreement with a previous study [7] that analyzed the general nutritional components of whole soybean curd. Unlike the previous study, crude fat was decreased significantly in this experiment and because of this result, whole soybean curd is expected to be effective as a diet food. After excluding the contents of crude protein and crude fat, carbohydrate content was found to be about twice higher than in pressed soybean curd because it included dietary fibers, which was consistent with the previous study [7]. Pressed soybean curd is presumed to lose a lot of water-soluble sugars during the pressing and shaping processes. More detailed studies on the dietary fibers and oligosaccharides contained in whole soybean curd are needed in the future.

Isoflavone content

The isoflavone content of whole soybean curd was analyzed and found to be 218 μ g/g, which was lower than in pressed soybean curd with 287 μ g/g, as shown in Table 4. Isoflavone content varies in different soybean species and this study cannot be compared with other studies due to the lack of analytic studies on the isoflavone content of whole soybean curd. However, given that the yield rate of whole soybean

Table 5. Hunter's color value in different soybean curds

	Hunter's color value			
	L (lightness)	a (redness)	b (yellowness)	$\Delta E^{(1)}$
Pressed soybean curd	81.37 $\pm$ 0.14 ^a	0.02 $\pm$ 0.01 ^a	13.30 $\pm$ 0.23 ^c	20.24 $\pm$ 0.25 ^b
Whole soybean curd	81.29 $\pm$ 0.15 ^a	-1.14 $\pm$ 0.03 ^b	14.62 $\pm$ 0.06 ^b	20.82 $\pm$ 0.09 ^b

¹⁾ ΔE means color difference.Values are mean $\pm$ SD.Different letters within a column indicate significant differences ($p < 0.05$) at $\alpha = 0.05$ as determined by Duncan's multiple range test ($a > b > c$)**Table 6.** Texture properties of different soybean curds

	Texture properties				
	Hardness(g)	Springiness	Cohesiveness	Adhesiveness	Chewiness
Pressed soybean curd	776.43 $\pm$ 48.92 ^a	0.91 $\pm$ 0.02 ^{ns}	0.67 $\pm$ 0.05 ^{ns}	-21.40 $\pm$ 4.47 ^{ns}	471.93 $\pm$ 77.90 ^{ns}
Whole soybean curd	645.77 $\pm$ 17.00 ^b	0.93 $\pm$ 0.02	0.72 $\pm$ 0.03	-26.73 $\pm$ 14.23	432.07 $\pm$ 11.05

Values are mean $\pm$ SD.

ns: not significant.

Different letters within a column indicate significant differences ($p < 0.05$) at $\alpha = 0.05$ as determined by Duncan's multiple range test ($a > b > c$).**Table 7.** Antioxidant activities in different soybean curds

	Total phenol (mg GAE/g)	Total flavonoid (mg RE/g)	DPPH (%)	ABTS (%)
Pressed soybean curd	32.83 $\pm$ 0.61 ^b	81.58 $\pm$ 2.89 ^{ns}	21.90 $\pm$ 0.003 ^b	31.00 $\pm$ 4.57 ^c
Whole soybean curd	37.13 $\pm$ 0.53 ^a	81.58 $\pm$ 1.44	28.28 $\pm$ 0.010 ^a	45.25 $\pm$ 0.59 ^a

Values are mean $\pm$ SD.^{abc}Different letters within a column indicate significant differences ($p < 0.05$) at $\alpha = 0.05$ as determined by Duncan's multiple range test ($a > b > c$)

ns: not significant.

curd in this experiment was increased by approximately 1.9 fold compared with pressed soybean curd and that its water content was high, the concentrations of bioactive substances were likely to be reduced.

Quality characteristics

Chromaticity

The surface color of whole soybean curd was measured by a chromameter and the results are as shown in Table 5. The L value indicating the brightness (L) was similar and the a value of whole soybean curd indicating the redness was lower than regular soybean curd, whereas the b value of whole soybean curd indicating the yellowness was significantly higher ($p < 0.05$). That is, whole soybean curd was shown to be lower in redness and higher in yellowness than regular soybean curd.

Texture

The mechanical properties of whole soybean curd were analyzed and the results are as shown in Table 6. Compared with pressed soybean curd, only the hardness value of whole soybean curd was significantly reduced, whereas the springiness, cohesiveness, adhesiveness and chewiness were all

similar. Therefore, this result indicates that whole soybean curd has a softer texture than pressed soybean curd. This is likely due not only to the omission of the physical pressing process during the manufacturing of whole soybean curd, but also to the coagulators used and the content of soluble dietary fibers. Nowadays, consumers prefer soft properties and the softness of whole soybean curd provides excellent distinctiveness for developing diet products and various whole soybean curd products not restricted to side dishes.

Antioxidant activities

The antioxidant substances and antioxidant activities of whole soybean curd was analyzed and the results are as shown in Table 7. As the yield rate of whole soybean curd was increased by 1.9-fold compared with pressed soybean curd, the contents of most nutrients and bioactive substances were decreased. However, the total amounts of phenol, DPPH scavenging activity and ABTS were significantly increased, indicating excellent antioxidant activity. These results suggest that whole soybean curd has a higher potential of being developed as healthy and diet food than pressed soybean curd.

CONCLUSION

During the production of whole soybean curd, the manufacturing time was shortened by omitting the processes of soaking and pressing. Price-competitiveness was secured by increasing the production yield rate by 1.9-fold. In this study, the nutritional components, bioactive substances, quality characteristics and antioxidant activities of whole soybean curd were analyzed and the results showed that the contents of nutrients and isoflavones were reduced to a certain extent, whereas carbohydrates including dietary fibers and antioxidant activity were significantly increased. In addition, due to the omission of the pressing process, water content was increased and the soft properties were improved. This facilitates the development of products that can be eaten in a variety of containers unlike regular soybean curd. Therefore, diverse whole soybean curd products supplemented with minor ingredients such as fruits, nuts, seaweed, etc. according to the desired taste and functionality are likely to be released in the future. These products are expected to be utilized in the diet market and as food for infants, the elderly and patients.

REFERENCES

- [1] Shon HS. History of soybean curd in Korea and development of new soybean curd. *Minjok Kwa Munhwa*. 1997;6:72-92.
- [2] Lee MJ, Sohn CY and Kim JH. Relation Between Health Examination Outcome and Intake of Soy Food and Isoflavone among Adult Male in Seoul. *Korean J Nutr* 2008;41(3):254-63.
- [3] Park KH, Piao XM, Jang EK, Yoo YE, Hwang TY, Kim SL, Jong JH, Shin HM and Kim HS. Variation of Isoflavone Contents in Korean Soybean Cultivars Released from 1923 to 2006. *Kor. J. Breed. Sci.* 2012;44(2): 149-59.
- [4] Suh JW, Hong SH and Lee HK. The study of hypothesis on the origin of bean curd. *The Korean acsdemin society of culture & tourism res.* 2006;8:65-8.
- [5] Kim KM, Lee S, and Hwang IK. Physicochemical Properties of Soybean Leaf by Cultivar and Development of Soybean Curd Prepared with Soy Leaf Power. *Korean J. Food Cookery Sci.* 2011;27(5):557-65.
- [6] Cho ST. Review of Predominant Characteristics of Tofu Coagulated by Calcium Lactate. *J. Korean Soc. Food Sci.* 2004;33:412-19.
- [7] Lee HJ, Shin HC, Lee YS, Kim JY, Moon YH, Park KH and Moon JH. Comparison of Quality Characteristics of Soybean Curd and Whole Soybean Curd. *Korean J. Food Sci. Technol.* 2009;41(2):117-21.
- [8] Shim JJ, Seo JH, Soh HS, Yoo BS and Lee SP. Rheological properties of soybean milk and curd prepared with micronized full-fat soyflour. *J.Korean Soc.Food Sci Nutr.* 2003;32(1):75-81.
- [9] Lee YT. Quality characteristics and antioxidative of soybean curd containing small black soybean. *Korea Soybean Digest.* 2007;24:14-22.
- [10] Park CK, Hwang IK. Effects of coagulant concentration and phytic acid addition on the contents of Ca and P and rheological property of soybean curd. *Korea J. Food Sci. Technol.* 1994;26:355-8.
- [11] Lee JK, Jeong JH and Lim JK. Quality Characteristics of Topokki dduk With Respect to Added Whole Woybean Curd (Chun-Tofu) by Different Storage Time. *Korean J. Food Cookery Sci.* 2012;28(2):111-21.
- [12] Korean Food & Drug Administration. Food Standards Codex. Korean Foods Industry Association, Seoul, Korea. 2007;599-637.