KOREAN J. FOOD SCI. TECHNOL.
Vol. 24, No. 1, pp. 97~100(1992)

Separation of Tofu-residue (*biji*) into Dietary Fiber and Protein Fractions

Won Jong Lee, Mi Ra Choi and Frank W. Sosulski*

Department of Food Science, Kang Nung National University
**Department of Crop Science and Plant Ecology, University of Saskatchewan*

콩비지의 식이섬유와 단백질 분리

이원종 · 최미라 · 소설스키*

강릉대학교 식품과학과, *캐나다 싸스캐치완대학교 작물학과

Abstract

Tofu-residue (biji) which was made on a laboratory scale from the three U.S. and three Korean soybean varieties contained approximately 57% dietary fiber, 20% protein, while the commercial residue contained 59% dietary fiber and 17% protein. The percent soluble fiber in total dietary fiber were 3% and 46% for residue and tofu, respectively. The tofu-residue was wet milled by blade grinding once or twice, followed by sieving and centrifugation of the liquid fraction. For twice-ground residue, the dietary fiber content increased from 58.7% to 80.6% in the sieved residue, with a fiber recovery of 90.4%. On the other hand, twice-ground centrifuged solids contained 46.8% protein, representing 42.4% of the total protein. Lipid levels in the sieved residue were much lower than in the original residue.

Key words: tofu-residue, dietary fiber, protein

Introduction

Tofu (soybean curd) is one of the important nonfermented soybean products which has been widely used in a variety of dishes by oriental people for many centuries. This is a highly digestible and nutritive product, and it also serves as an inexpensive protein source for man. The insoluble residue produced during the straining process has a high moisture content and it provides a good medium for microbial growth. If it is to be used for food or feed, it should be consumed promptly, or dried or refrigerated before spoilage occurs. Hackler *et al*[1] reported that the residue has a mean protein content of 24.0% and a mean fat content of 15.2%. Bourne *et al*[2] found that the crude fiber of the residue was very high, with a mean of 14.5%. These studies indicate that the degree of extraction of protein into tofu was insufficient and further processing of the residue might increase dietary fiber content in the high fiber fraction and release more protein into the high protein fraction.

The objectives of the present investigation were to determine the composition and dietary fiber content of tofu-residue on a laboratory and a commercial scale, and to mechanically disintegrate the residue, followed by sieving and centrifugation to obtain a high fiber fraction and a high protein fraction.

Materials and Methods

Preparation of tofu-residue on a laboratory scale

Three Korean soybean varieties: Paldal, Dukyoo and Jangup, and three U.S. soybean varieties: Hack, Century 84 and Burlison, were used. Tofu-residue was propared by the method of Wang and Hesseltine[3] except that the soaked beans were homogenized in a Waring blender.

Analytical methods

Moisture, protein, lipid and ash contents were determined by the procedures of the AACC[4]. Protein content was calculated using the nitrogen-to-protein conversion factor of 5.7, based on the recommendation of Sosulski and Imafidon[5]. Total dietary fiber was qua-

Corresponding author: Won Jong Lee, Department of Food Science, Kang Nung National University, Kang Nung, Kangwon-do 210-702, Korea

Table 1. Chemical composition of soybeans on a dry weight basis (%)

Variety	Moisture	Protein	Dietary fiber	Lipid	Ash
Korean					
Paldal	13.4	39.6	20.6	17.9	5.1
Dukyoo	12.6	37.0	21.6	18.4	5.4
Jangup	11.3	36.2	20.9	19.7	5.4
Mean	12.4	37.6	21.0	18.7	5.3
U.S.					
Burlison	6.7	37.8	16.6	20.1	5.3
Century84	6.9	37.8	20.0	19.2	5.1
Hack	6.6	33.7	18.7	22.0	5.1
Mean	6.7	36.4	18.4	20.4	5.2

ntitated by the enzymatic gravimetric method of Prosky *et al*[6] except that the protein correction was also based on N×5.7, rather than 6.25. Water and oil absorption capacities were determined by the centrifuge procedures described in Sosulski[7] and Lin *et al*[8], respectively.

Separation of tofu-residue into dietary fiber and protein

Fresh tofu-residue samples were collected from a local tofu plant (Kang Nung tofu plant, Kang Nung, Korea). The residue was assayed for moisture and dry matter determination before processing or storage at −20C. A Waring blender was used to provide size reduction of residue particles by the cutting action of revolving blade operated at 20,000 rpm. For one treatment, the residue (100g) was ground for 2 min with 300 m*l* of distilled water before sieving (210 μm sieve, Spectrum Medical Industries, Inc., Los Angeles, CA) and washing with 100 m*l* of distilled water. In the next treatment, the above residue was returned for a second 2 min grinding in 300 m*l* of distilled water before fractionation. The liquid fraction (throughs of the 210 μm sieve) was centrifuged at 10,000×g for 10 min to obtain the centrifuged solids (CS) fraction.

Results and Discussion

Chemical composition of soybeans

Table 1 lists the proximate composition of the soybeans. Due to differing storage conditions, the beans from Korea had consistently higher moisture contents than those from U.S. The Korean soybeans had a mean protein content of 37.6% which was higher than the mean value of 36.4% for the U.S. soybeans. However, the U.S. soybeans had a mean crude fat content of 20.4% which exceeded the mean value of 18.7% for the Korean soybeans. Wang *et al*[9] reported that significant varietal differences were noted for protein and oil contents of soybeans, but the protein and oil contents of the soybeans were negatively correlated. Similar relationships were observed among samples within each location, as well as between the two locations.

Table 2. Yields of tofu and tofu-residue from 100g of soybeans

		Wet basis		Dry basis
		g	moisture	g
Tofu				
	Padal	331.6	84	55.0
	Dukyoo	243.5	79	51.2
	Jangup	239.6	78	52.6
	Burlison	318.6	83	54.2
	Century84	289.7	82	53.8
	Hack	275.4	81	52.3
	Mean	283.1	81	53.2
Residue				
	Padal	124.1	79	26.8
	Dukyoo	123.3	78	27.2
	Jangup	112.7	78	25.1
	Burlison	114.0	79	23.8
	Century84	109.2	78	24.4
	Hack	119.7	78	26.0
	Mean	117.2	78	25.6

Table 3. Chemical composition of tofu on a dry basis (%)

Variety	Protein	Lipid	Dietary fiber	Ash
Korean				
Paldal	52.4	27.5	6.0	6.6
Dukyoo	49.5	31.3	4.7	5.7
Jangup	48.3	31.0	4.1	5.5
Mean	50.1	29.9	4.9	5.9
U.S.				
Burlison	49.8	30.2	5.7	5.4
Century84	48.4	31.9	6.0	5.5
Hack	46.5	34.3	4.6	5.8
Mean	48.2	32.1	5.4	5.6
Total				
Mean	49.2	31.0	5.2	5.8

Chemical composition of tofu and tofu-residue

Tofu-residue was made on a laboratory scale from the three U.S. and three Korean soybean varieties. The average yields of tofu and residue from 100g of soybeans were 117.2g and 283.1g on a wet basis, and 25.6g and 53.2g on a dry basis, respectively (Table 2). The

Table 4. Chemical composition of tofu-residue on a dry basis (%)

Variety	Protein	Lipid	Dietary fiber	Ash
Korean				
Paldal	21.9	9.9	56.9	3.8
Dukyoo	21.2	12.3	55.1	3.5
Jangup	18.7	12.0	59.2	3.8
Mean	20.6	11.1	57.1	3.7
U.S.				
Burlison	18.7	10.1	58.4	3.5
Century84	21.2	11.4	55.5	3.5
Hack	18.4	14.2	56.6	3.4
Mean	19.4	11.9	56.8	3.5
Total				
Mean	20.0	11.5	57.0	3.6

Table 5. Composition of dietary fiber in soybean, tofu and tofu-residue

Component	Soybean	Tofu	Residue
Soluble	2.5%	2.1%	1.4%
Insoluble	16.2%	2.5%	54.6%
Total	18.7%	4.6%	56.0%
% soluble in TDF	13.4%	45.7%	2.5%

moisture contents of tofu and residue were approximately 81% and 78%, respectively. The yields of tofu, wet and dry basis, were generally proportional to the contents of protein plus lipid in the original soybeans.

The mean protein and lipid contents of tofu wre 49.2% and 31.0%, respectively (Table 3). The mean dietary fiber content of tofu was only 5.2%. However, the dietary fiber of the residue was very high, with a mean of 57.0% and a range of 55.1～59.2% (Table 4). The mean protein and fat contents in the residue were 20.0% and 11.5%, respectively on a dry basis. Wang and Cavins[10] reported that the residue contained 27.1% protein and 7.6% oil. The percent soluble fiber content in the total dietary fiber of soybean (Hack variety) was 13.4% (Table 5). Most of the soluble fiber was separated into the tofu, showing a high percentage of 45.7% for soluble in total dietary fiber. The soluble fiber content, as a percentage of total dietary fiber in the residue was, only 2.5%.

Table 6 shows the composition of the commercial tofu-residue sold in Korea. The moisture content of 84% was higher than the moisture content of 78% in laboratory residue. The dietary fiber levels ranged from 54.6～62.5% with a mean value of 59.1%, while protein contents ranged from 16.2～18.0% with a mean value of 17.3%. The lipid level averaged 9.8%. The

Table 6. Chemical composition of commercial tofu-residue on a dry basis (Hack variety) (%)

Sample	Solid content	Protein	Lipid	Dietary fiber	Ash
A	13.2	17.1	11.4	60.4	3.2
B	14.5	17.7	8.4	54.6	3.2
C	17.2	16.2	8.0	62.5	3.4
D	19.6	18.0	11.3	58.7	3.6
Mean	16.1	17.3	9.8	59.1	3.4

Table 7. Effect of grinding treatments on yields of components from 100g of tofu-residue

Treatments	Sieved residue		Centrifuge Solid	
	As is	Dry basis	As is	Dry basis
No treatment	100	19.6	–	–
Blade ground(1X)	85.1	14.0	7.5	2.5
Blade ground(2X)	79.9	12.0	15.4	3.2

commercial process was slightly more efficient in separation of protein and fiber than the laboratory procedure.

Separation of residue into dietary fiber and protein

The tofu-residue sample which contained 19.6% dry matter (Table 6) was reprocessed by grinding once or twice, followed by sieving and centrifugation of the liquid fraction. A material balance of the solids recovered on the sieve or centrifuge are given in Table 7. After the single grinding, the yields of solids in sieved residue and centrifuged solids were 85.1 and 7.5g/100g original sample, with a loss of 15.8% of the dry matter into the aqueous phase. Two grindings fractionate the tofu-residue into 79.9% sieved residue and 15.4% centrifuged solids with 17.9% of dry matter being solubilized.

For twice-ground residue, the dietary fiber content increased from 58.7% to 80.6% in the sieved residue (Table 8) with a fiber recovery 90.4% (Table 9). On the other hand, twice-ground centrifuged solids contained 46.8% protein, representing 42.4% of the total protein, and only 3.7% of the total fiber. The lipids fractionated into the centrifuged solids, the levels being 32.8 % and 37.0%, respectively, in single and twice-ground fractions. Thus the fiber-rich fraction was not only greatly enhanced in fiber level but the lipid content was reduced to only 2.6% in the twice-ground products.

The water and oil absorptions of the untreated residue were very high relative to those of commercial

Table 8. Chemical composition and functional properties of fiber rich and protein rich products (%db)

Treatment	Dietary fiber	Crude protein	Lipid	Water absorption	Oil absorption
Fiber-rich residues					
No treatment	58.7	18.0	11.3	1091	368
Blade ground (1X)	77.0	11.3	4.5	1199	297
Blade ground (2X)	80.6	9.4	2.6	1276	267
Commercial wheat bran	53.4	18.2	4.0	424	294
Protein-rich centrifuged Solids					
Blade ground (1X)	14.2	47.3	32.8	–	–
Blade ground (2X)	13.2	46.8	37.0	–	–

Table 9. Effect of grinding treatments on the recovery of dietary fiber and crude protein in sieved residue(SR) and centrifuged solids(CS)

	Crude protein		Dietary fiber		Lipid	
	SR	CS	SR	CS	SR	CS
No treatment	100	–	100	–	100	–
Blade ground(1X)	44.8	33.5	93.7	3.1	28.4	37.0
Blade ground(2X)	34.4	42.4	90.4	3.7	15.1	53.5

wheat bran (Table 8). The water absorption capacities of blade ground residues were higher than the untreated residue. Contrary to the absorption of water, the blade ground residue bound less oil than the untreated residue. The functional properties and potential utilization of the centrifuged solids are the subject of continuing investigations.

요 약

실험실에서 제조된 비지는 약 57%의 식이섬유와 20%의 단백질을 함유한 반면, 시판용 비지는 약 59%의 식이섬유와 17%의 단백질을 함유하였다. 비지와 두부의 총식이섬유중 수용성 식이섬유는 3%와 46%를 차지하였다. 비지를 2회 분쇄후 사별하고 액체부분을 원심분리한 결과 체위의 비지 식이섬유함량은 58.7%에서 80.6%로 증가되었고 식이섬유회수율은 90.4%이었다. 원심분리후의 고형물은 46.8%의 단백질을 함유하였고, 단백질의 회수율은 29.2%를 나타냈다. 체위의 비지 지질함량은 처리전보다 훨씬 낮았다.

Acknowledgement

This study was supported by Non Directed Research Fund, Korea Research Foundation, 1990. The authors also thank Dr. Seok-dong Kim, Crop Experiment Station, R.D.A., Korea, and Dr. George Graef, Department of Agronomy, University of Nebraska, Lincoln, U.S.A. for supplying soybean samples.

References

1. Hackler, L.R., Stillings, B.R. and Polimeni, R.J. Jr.: Correlation of amino acid indexes with nutritional quality of several soybean fractions. *Cereal Chem.*, **44**, 638(1967)
2. Bourne, M.C., Clemente, M.G. and Banzon, J.: Survey of suitability of thirty cultivars of soybeans for soymilk manufacture. *J. Food Sci.*, **41**, 1204(1976)
3. Wang, H.L., and Hesseltine, C.W.: Coagulation conditions in tofu processing. *Proc. Biochem.*, **17**, 6(1982)
4. American Association of Cereal Chemists: Approved methods of the AACC., The Association, St. Paul, MN (1984)
5. Sosulski, F.W. and Imafidon, G.I.: Amino acid composition and nitrogen-to-protein conversion factors for animal and plant foods. *J. Agr. Food Chem.*, **38**, 1351 (1990)
6. Prosky, L., Asp, N.G., Furda, I., Devries, J.W., Schweizer, T.F., and Harland, B.A.: Determination of total dietary fiber in foods and food products. *J. Assoc. Off. Anal. Chem.*, **68**, 677(1985)
7. Sosulski, F.W: The centrifuge method for determining flour absorption in hard red spring wheats. *Cereal Chem.*, **39**, 344(1962)
8. Lin, M.J.Y., Humbert, E.S., and Sosulski, F.W.: Certain functional properties of sunflower meal products. *J. Food Sci.*, **399**, 368(1974)
9. Wang, H.L., Swain, E.W., Kwolek, W.F. and Fehr, W. R.: Effect of soybean varieties on the yield and quality of tofu. *Cereal Chem.*, **60**, 245(1983)
10. Wang, H.L. and Cavins, J.F.: Yield and amino acid composiition of fractions obtained during tofu production. *Cereal Chem.*, **66**, 359(1989)

(Received December 2, 1991)