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Effect of Solvents Washing on Chemical and Physical Properties of Dried Soymilk Residue

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溶媒処理에 의해 乾燥된 豆乳비지의 理化学的 性質에 관한 硏究

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Abstract

Soymilk residue was washed separately with acetone, ethanol, isopropyl alcohol and *n*-hexane, and then dried at 45°C. The dried residues were evaluated for drying rate, color and chemical and functional properties. Washing with acetone resulted in the shortest drying time (1hr) and the highest in protein content (48.8%) and in Hunter "L" value. The dried residues after treatment with acetone and alcohols showed relatively high values of 4.3-4.7*g/g* and 8.5-8.7*g/g* in oil and water absorption, respectively. Addition of the acetone treated residue to wheat flour at a level of 10% affected little in Amylograph viscosity while those treated with other solvents caused a significant decrease in the viscosity.

Introduction

Soybean production and its utilization for human food have been steadly increased as a low-cost and high protein source. Soymilk, one of the most promising soybean products, has been greatly improved its commercial acceptability with continuing efforts of many workers.[1,2,3] As the result, utiliation of the soymilk residue obtained as a by-product become to be major concern for soymilk processors. The amino acid composition of soymilk residue protein showed that sulfur containing amino acids are higher and available lysine is lower than those of soymilk protein.[4] They also found that PER value of soymilk residue was considerably higher than that of soymilk and was comparable to that of milk casein.[4,5] This most nutritious fraction of soybean has difficulty in use for human food due to rapid spoilage during storage.

In an attempt to extend storage life, dehydration was carried out by hot-air drying at atmospheric pressure.[6,7] They found, however, that the hot-air drying method is not proper because of surface hardening on the residue particles which has a tendency to be clustered. The resultant dried residue also developed brown color and rancidity due to high temperature treatment and required grinding before further use. Treatment of alcohol on soybean meal was introduced by Beckel *et al.*[8,9] and Belter *et al.*[10] They reported that alcohol treatment served as a debittering agent and reduced flavor and color of the soybean meal. Eldridge *et al.*[11] washed soybean protein isolate with alcohols and found that alcohol washing removed phospholipid-like material and improved color, flavor and foam stability.

Present study was conducted to investigate the effect of several solvents washing on drying rates of soymilk residue. The chemical composition, color and some physical properties of dried soymilk residue were also studied.

Materials and Methods

Materials

Soymilk residue was obtained from Chung's Foods Co., Ltd. (Seoul, Korea) where it was prepared by soaking mixed varieties of imported soybeans, dehulled by crushing, blanching and grinding with boiling water and centrifuged. The residue was stored at -20°C until solvent washing. Commercial soyprotein concentrates of Stapro and Procon (Staley MFG. Co. ILL.) were used for comparison of oil and water absorption characteristics. A commercial wheat flour having medium quality was used to prepare the mixture with dried soymilk residue for measurement of gelation properties.

Solvent Washings and Drying

All solvents used, acetone, isopropyl alcohol, ethanol and *n*-hexane, were ACS grade. A 15 *g* of soymilk residue containing 78.5% of moisture was mixed with 40 *ml* each of solvent and stirred with magnetic stirrer for 30 min. The mixture was filtered under reduced pressure over Whatman filter paper No. 42. The residue was removed into 100 *ml* beaker and washed two more times with 40 *ml* of solvent with 2 min of stirring. The filtrates of above were combined for absorbance measurement. The residue after filtration was dried at 45°C and measured their weights at every hour.

Analytical Methods

Moisture, lipids and fiber were determined according to the methods of AOAC.[12] Nitrogen was analyzed by micro Kjeldahl method[12] and a conversion factor of 6.25 was used for the estimation of protein. Nitrogen free extract was calculated by substracting the sum of other constituents assayed from 100. Color evaluation of solvents washed and dried residues was made on the values of the "L", "a", "b", "yellow index" and "white index" using a Hunter model D 25 A color difference meter. The filtrate of each solvent after washing the residue was measured for absorbances at 440 *nm*, 520 *nm* and 630 *nm* using a Bausch and Lomb Spectronic 20 spectrophotometer.

Oil and Water Absorption

A method of oil and water absorption measurements described by Beuchat[13] was employed. A 1 *g* of solvent washed and dried residue was taken in 50 *ml* centrifuge tube and added 10 *ml* of soybean oil or 10 *ml* of distilled water. The tubes were stirred for 30 sec on a vortex stirrer and then allowed to stand at room temperature (21°C) for 30 min followed by centrifugation at 10,000 x G for 30 min. The supernatant of water or oil were carefully decanted and measured the volume. The difference between the amounts added and supernatant were expressed as oil and water absorption on a dry weight basis.

Pasting Properties

Effect of soymilk residue addition to wheat flour on starch gelation properties were determined with a Brabender Visco/Amylograph, Model VA-VE, equipped with a 700 *cm·g* cartridge operated at 75 rpm bowl speed. The addition of the residue to wheat flour was ranged from 0 to 40%. A 46 *g* (dry weight basis) of the mixtrue of wheat flour and dried soymilk residue was suspended in 350 *ml* of distilled water and mixed

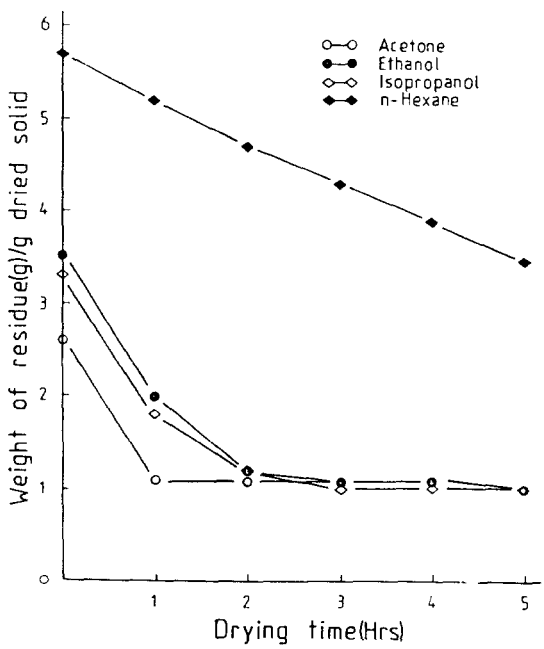

Fig. 1. A typical drying curve of soymilk residue at 45℃ after treatment with various solvents

thoroughly. The suspended mixture was transferred quantitatively into the amylograph bowl with addition of 64 *ml* of distilled water. All of these processes were done within 3—4 min. The temperature of this mixture was raised from 25°C to 92.5°C at a rate of 1.5°C/min, held at 92.5°C for 5 min and then allowed to cool to 30°C.

Results and Discussion

Drying and Analytical

Fig. 1 shows the drying rate of solvent washed and filtered soymilk residue. The initial solid contents of filtered residue were 28.7% for acetone, 27.8% for ethanol, 30.5% for isopropyl alcohol and 16.4% for *n*-hexane. After drying at 45°C for one hour, solid contents increased to 91.2%, 54.8%, 46.0%, 18.9% for acetone, ethanol, isopropyl alcohol and *n*-hexane, respectively. The result indicate that acetone treatment on the residue was most effective for drying while ethanol and isopropyl alcohol washed samples required 2—3 hours. The slowest one in drying was *n*-hexane washed residue which exhibited sticky colloidal form. It is probably due to immiscibility between water and *n*-hexane and water was retained in the residue. The decreases of residue weights were mainly caused by solvent evaporations. Use of the above first three solvents for washings of the soymilk residue were very effective for drying when it is compared to the result of Choi[7] which required 3 hrs at 80°C and 2.5 hrs at 100°C. The chemical composition of dried soymilk residues are shown in Table 1. Solvent washings with acetone, ethanol and isopropyl alcohol on soymilk residue resulted an increasein protein contents in total solids and a substantial reduction in lipids as compared with those values of unwashed residue as one could expected.

Table 1. Composition of dried soymilk residues after treatments with various solvents

Solvents	Analysis, % (moisture free basis)					
	Yield	Protein	Lipids	Fiber	Ash	NFE
Untreated residue	100	43.1	19.9	11.1	4.2	21.7
Acetone	80.0	48.8	5.6	10.8	4.0	30.8
Ethanol	82.5	46.9	9.9	10.1	3.6	29.5
Isopropanol	87.3	46.3	11.1	9.4	3.8	29.4
n-Hexane	98.5	42.5	18.9	9.5	4.2	24.9

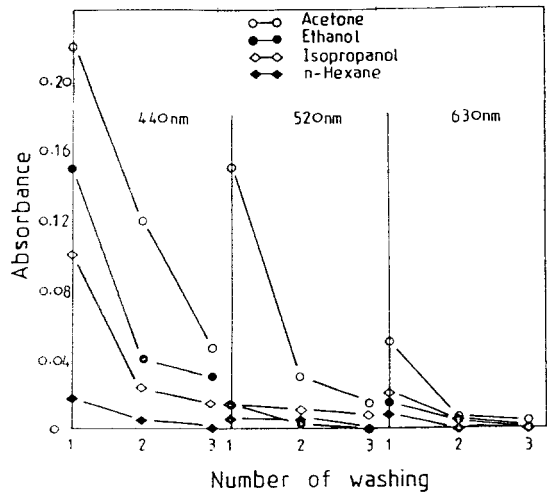

Fig. 2. Changes in absorbances of filtrates at 440 *nm*, 520*nm* and 630*nm*

The ash contents for all solvents treated samples were close to untreated one. It was noticeable that *n*-hexane washed residue caused the least changes in composition. The increase of protein content and the drying rate for the other three solvents can be explained by the different solubility of lipids for the solvents used and their polar characteristics.

Color Evaluation

The filtrates after washing the residue with the solvents for 30 min were measured for their absorbances at 440 *nm*, 520 *nm* and 630 *nm*. Absorbances of the filtrates after first, second and third washings are shown in Fig. 2. The changes of absorbances clearly indicate that most of the color materials were removed by first washing. The most of color substances removed was in the region of violet, and red colored material was minimum. The acetone washing was the most effective to remove the color substances while *n*-hexane was the least.

These results corresponded to the Hunter values of dried soymilk residues (Table 2). The values of Hunter

Table 2. Hunter values of dried soymilk residues after solvents washing for 30min

Solvents	Hunter values				
	"L"	"a"	"b"	"Yellow -index"	"White -index"
Acetone	104.50	3.26	5.27	11.59	77.34
Ethanol	102.11	1.79	6.61	13.14	65.73
Isopropylalcohol	102.59	4.10	5.41	12.59	73.56
n-Hexane	90.01	2.51	15.40	32.29	1.84

Table 3. Comparison of oil and water absorption characteristics of dried residues

	Oil absorption (*g*/*g*)	Water absorption (*g*/*g*)
Acetone	4.3	8.5
Ethanol	4.9	8.7
Isopropyl alcohol	4.7	8.6
n-Hexane	2.3	5.0
SPC-1*	1.4	3.1
SPC-2*	1.1	2.3

* Commercial soyprotein concentrates

"L" and "white-index" showed that acetone treated one exhibited the highest among the solvents used. The low values of Hunter "b" and "yellow-index" were found for all solvents washing except *n*-hexane while ethanol washed sample had the lowest in "a" value. From these results, the overall color evaluation for the solvent washed residues, showed that acetone was superior in terms of removing color substances to other solvents used in this experiment. Ethanol and isopropyl alcohol washings resulted a close Hunter values to that of acetone washing while *n*-hexane had the least effect on color improvement of the residue.

Oil and Water Absorption

Results of the oil and water absorption are presented in Table 3. It shows that solvent washed soymilk residues had much higher values in water and oil absorptions than commercial soyprotein concentrates. The solvent washed samples except *n*-hexane exhibited relatively high values in oil absorption, 4.3—4.9 *g* of oil/*g* residue. In water absorption of ethanol, isopropyl alcohol and acetone washing also showed values of 8.5—8.7 *g*/*g* residue which were approximately 2—3 times of the value of commercial soyprotein concentrates. These results are also much higher than those values of soybean flour and soybean concentrates reported to have 2.4 and 3.6 *g*/*g*, respectively.[14]

Higher oil and water absorption capacities of the residues washed with acetone and alcohols over *n*-hexane treated one was probably due to the ability to remove the soluble materials along with color substances. Similarly Eldridge *et al.*[11] studied the effect of various solvents treatments on the foam stability of soybean protein and found that washing with methanol, ethanol or isopropyl alcohol improve the stability greatly and suggested the improvement of foam stability was

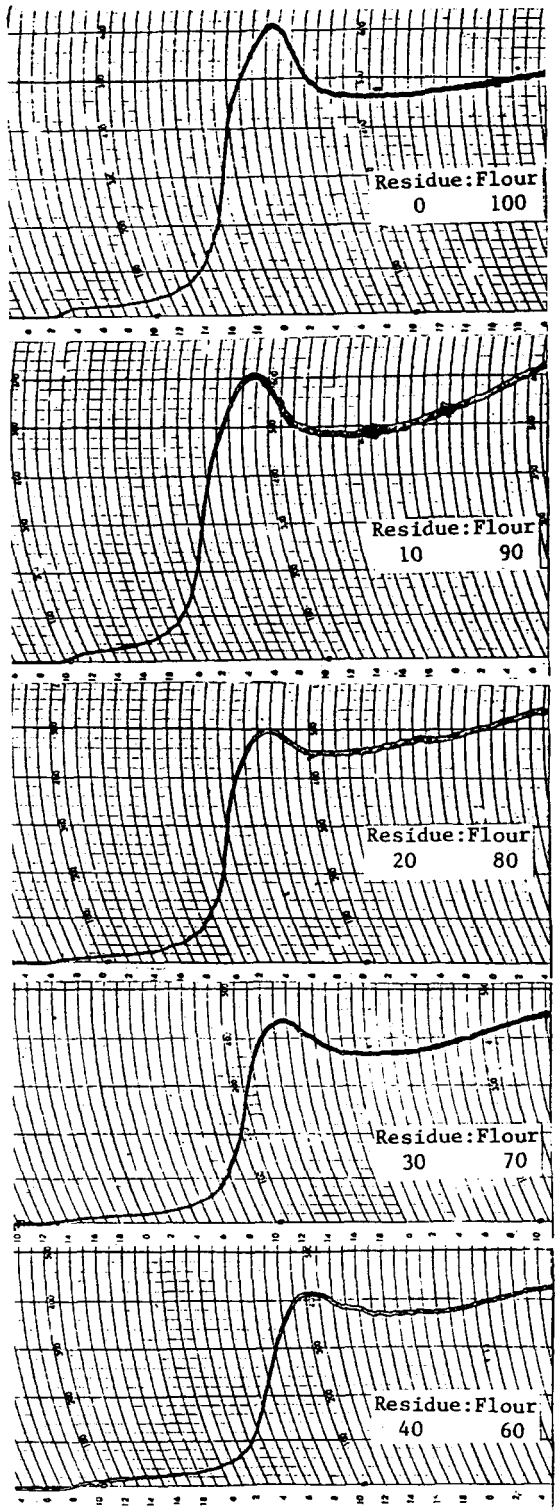

Fig. 3. Brabender amylograms of mixture of wheat flour and acetone washed soymilk residue

Table 4. Amylogram data on the mixtures of wheat flour and solvents treated soymilk residues (10% solid basis)

Solvents used	% SR	Initial pasting temperature (℃)	Peak viscosity (B.U.)	Peak temperature (℃)	Viscosity at 92.5℃ (B.U.)	5-Min Height (B.U.)
	0	63.0	610	90.5	480	470
	10	73.5	600	90.5	495	490
Acetone	20	65.0	500	90.0	460	450
	30	61.0	440	90.0	400	370
	40	59.5	415	83.0	375	370
	0	63.0	610	90.5	480	470
	10	63.0	545	90.0	490	495
Ethanol	20	62.0	455	88.0	385	390
	30	60.5	365	88.5	350	355
	40	57.0	330	89.0	315	320
	0	63.0	610	90.5	480	470
	10	61.0	500	90.0	430	420
Isopropanol	20	62.0	440	90.0	415	410
	30	57.5	440	91.0	420	425
	40	58.0	415	90.0	390	390
	0	63.0	610	90.5	480	470
	10	65.5	530	89.0	455	460
n-Hexane	20	68.5	335	89.0	320	315
	30	66.0	300	90.0	275	280
	40	74.0	150	90.0	155	170

WF = wheat flour

SR = dried soymilk residue

contributed by removal of the impurities.

Pasting Properties

Typical amylograms of wheat flour and the mixture of soymilk residue and wheat flour are illustrated in Fig. 3. As more soymilk residue was added to the wheat flour, viscosities and initial pasting temperature were shown to be decreased. Changes in amylogram data for the mixture ranges of 0—40% of dried soymilk residue added to the wheat flour is presented in Table 4. All of the values were generally decreased as the mixing ratio increased except initial pasting temperature of *n*-hexane washed sample. For the acetone treated sample, it was particularly noticeable of little change in peak viscosity and peak temperature at 10% level. Initial pasting temperature, viscosity at 92.5°C and 5-min Height were rather increased. A rapid decrease in peak viscosity of 610 B.U. was observed for acetone, ethanol, isopropyl alcohol and *n*-hexane treated samples to 415 B.U., 330 B.U., 415 B.U. and 150 B.U., respectively, when they were mixed up to 40%.

The results obtained from this study suggest that solvents washing with acetone, ethanol and isopropyl alcohol was very efficient in soymilk residue drying and improvement of color. Oil and water absorption properties were considerably high and pasting properties was hardly affected at 10% addition level. A further work would be desirable for finding a proper mixing ratio of solvent and wet residue, and addition of this residue as a supplement of foodstuffs.

要 約

蛋白質이 39.4%(건량기준) 함유된 豆乳 生産時 생기는 豆乳비지의 乾燥를 위하여 acetone, ethanol, isopropylalcohol 및 *n*-hexane으로 溶媒洗滌을 한 뒤 各 溶

媒별로 처리된 비지를 45℃에서 건조하였다. 건조비지의 일반성분은 단백질 42.5%~48.8%, 지방질 5.6%~18.9% 및 섬유질 3.6%~4.2%이었으며 乾燥中의 乾燥速度 그리고 乾燥비지의 色相 및 물리적 성질등을 비교하였다. Acetone처리된 비지가 가장 빨리 乾燥되었으며 다음은 ethanol, isopropyl alcohol, *n*-hexane 순이었고 또한 acetone処理된 乾燥비지의 粗蛋白質 함량은 48.8%로 제일 많았고 粗脂肪은 5.6%로 제일 낮았다. Hunters color difference meter로 측정된 乾燥비지의 Hunter값들은 "L" value에서는 acetone処理区가 가장 높았고 "a"와 "b" value에서는 acetone과 isop-ropylalcohol処理区가 다른 溶媒処理区보다 낮았다. 乾燥된 비지의 水分과 기름의 吸収能力 비교에서 acetone과 ethanol処理区가 다른 処理区보다 높은 값을 보여주었으며 乾燥비지를 밀가루에 섞어 Amylograph로 측정된 粘度의 변화를 보면 비지 添加量이 10%에서 40%로 증가하면서 粘度가 감소하였으나 acetone処理区로서는 10% 添加하였을 때 거의 영향이 없었다. 이상의 結果에서 豆乳비지의 acetone 또는 ethanol로 처리함이 豆乳비지의 乾燥를 위하여 乾燥速度나 蛋白質함량 그리고 色相 및 Amylograph粘性의 성질에서 우수함을 보여주어 実用化를 위한 가능성을 보여주었다.

References

1. Johnson, K. W. and Snyder, H. E. : *J. Food. Sci.*, **43**, 349 (1978)
2. Nelson, A. I., Steinberg, M. P., and Wei, L. S. : *J. Food Sci.*, **41**, 51 (1976)
3. Johnson, L. A., Deyoe, C. W., and Hoover, W. J. : *J. Food Sci.*, **46**, 239 (1981)
4. Hackler, L. R., Stillings, B. R., and Polimeni, R.J. Jr. : *Cereal Chem.*, **44**, 638 (1967)
5. Hackler, L. R., Hand, D. B., Steinkraus, K. H., and Van Buren, J. P. : *J. Nutrition*, **80**, 205 (1963)
6. Chung, S. S., Chang, H. N., and Park, M. Y. : *Korean J. Food Sci. Technol.*, **10**, 1 (1978)
7. Choi, S. Y. : *M. S. Thesis*, Korea Univ. Korea (1982)
8. Beckel, A. C., Belter, P. A., and Smith, A. K. : *J. Am. Oil Chem. Soc.*, **25**, 7 (1948)
9. Beckel, A. C., Belter, P. A., and Smith, A. K. : *J. Am. Oil Chem. Soc.*, **25**, 10 (1948)
10. Belter, P. A., Beckel, A. C., and Smith, A.K.: *Ind. Eng. Chem.*, **36**, 799 (1944)
11. Eldridge, A. C., Wolf, W. J., Nash, A. M., and Smith, A. K. : *J. Agr. Food Chem.*, **11**, 323 (1963)
12. AOAC. : *Official Methods of Analysis*, 11th ed., Association of Official Analytical Chemists, Washington, D. C. (1970)
13. Beuchat, L. R. : *J. Agr. Food Chem.*, **25**, 258 (1977)
14. Sosulski, F. W. and Fleming, S. E. : *J. Am. Oil Chem. Soc.*, **54**, 100A (1977)

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