Research Article

Kinetics and Characteristics of Soybean Oil and Protein Extracted by AOT Reverse Micelle Technology

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The mass transfer process of soybean oil extracted by AOT reverse micelle was determined. Meanwhile, the physicochemical properties of oil and structural properties of protein were also investigated by gas chromatography (GC), Fourier infrared spectrum (FTIR), and amino acid analyzer. The results indicated that the mass transfer model can be set up as $1 + 2(1 - x) - 3(1 - x)^{2/3} = 0.248 \cdot \exp(-720.8/T) \cdot t$. The reaction probably belongs to internal diffusion. The oil extracted by AOT reverse micelle was in better quality according to physicochemical analysis. The soybean protein almost retained its original structure in AOT reverse micelle by FTIR and amino acid analysis. Therefore, AOT reverse micelle is an attractive procedure for extracting oil and protein simultaneously.

1. Introduction

Soybeans, as a source of both protein and oil for human food and animal feed, are the world's most valuable legumes. Soybean protein, which comprises approximately 40% of the raw bean, is widely used in food for animals and humans for its high nutritional and excellent functional properties [1]. Meanwhile, soybean oil, as the world's largest source of vegetable oil, contains high levels of polyunsaturated fatty acids, and it too is widely used in many industries. The problem is that current methods for oil and protein extraction can adversely affect the structural and chemical properties of both the oil and protein, thereby compromising their efficacy in applications [2, 3].

Many oil and protein preparation methods, physical, chemical, and enzymatic, have been reported [4–6]. In recent years, a new method, reverse micelle technology, has emerged. Researchers have reported important advantages of this technology, such as simple operation, large-scale sample loading, and continuous operation [7].

Reverse micelles are formed by self-assembly of the surfactant in the bulk organic solvents. The hydrophilic part of the surfactant is directed toward the interior of the micelle and forms a polar core in which water can be solubilized [8]. Thus, the polar pool is able to solubilize large amounts

of water and hydrophilic substances such as amino acids and proteins [9, 10]. The most widely used reverse micellar system developed so far uses sodium bis(2-ethylhexyl) sulfosuccinate (AOT) as amphiphilic surfactant. The AOT reverse micelle system has been used for large-scale separation of amino acids, peptides, enzymes, and proteins [10–13]. Meanwhile, researchers have also reported that reverse micelle systems can be used to separate oil and protein from oil crops simultaneously [14].

Reverse micelles exhibit dynamic behavior in an organic solvent. Researchers have reported that the dynamic behavior of reverse micelles determines the protein nanoparticle size [15]. Meanwhile, the refolding kinetics of the reduced, denatured hen egg white lysozyme in AOT reverse micelles also have been investigated [16]. Yang et al. [17], in examining the dynamic process of peanut protein extracted by enzyme-containing reverse micelles, found that the rate-determining step in this extraction process may be the internal diffusion control. Meanwhile, Guo et al. [18] reported that the backward extraction of protein in AOT reverse micelle was controlled by interfacial resistance. Researches on mass transfer process are helpful for creating a reverse micelle extraction process of oil and protein. However, there is still limited information available on the dynamics of oil extracted by reverse micelle technology.

FIGURE 1: Schematic illustration of the extraction of oil and protein by AOT reverse micelle.

The present study investigated the dynamics model of oil extraction by reverse micelle technology. Meanwhile, the physicochemical properties of oils and protein structures were also studied by gas chromatography (GC), Fourier infrared spectrum (FTIR), and amino acid analyzer. The results can improve applications of reverse micelle system in the food industry.

2. Materials and Methods

2.1. Materials. Full-fat soybean powder was purchased from Anyang Mantianxue Food Manufacturing Co., Ltd. (Henan, China). AOT was obtained from Shanghai Haiqu Chemical Co., Ltd. (Shanghai, China). Other chemicals were of analytical grade.

2.2. Prepared of the AOT Reverse Micelle System. AOT (0.06 g/mL) was dispersed in isooctane (200 mL) in the conical flask and oscillated at room temperature. When the AOT was completely dissolved, KCl-phosphate buffer solution (0.1 mol/L, pH 7.0) was added. After that, the AOT reverse micelle system was left at room temperature until it became transparent, an indication that the solution had stabilized [14].

2.3. Oil and Protein Extraction. A schematic diagram of the extraction of oil and protein by reverse micelle was shown in Figure 1. The first step was the oil and protein extraction was mixing the soybean flour with an AOT reverse micelle system using digital thermostatic water bath oscillators for 40 min. After that, the mixture was centrifuged at 4000 r/min for 25 min. The reaction mixture was designated as forward extraction liquid. The same volume of KCl-phosphate buffer

solution (1.0 mol/L, pH 8.0) was mixed with the forward extraction liquid and oscillated for 60 min to break up the reverse micelle system. The mixture was centrifuged at 4000 r/min for 25 min. The water phase (Figure 1) was dialyzed at 4°C for 24 h to obtain protein solution and recovered by freeze-drying. Meanwhile, soybean oil from the organic phase was separated by using a rotary vacuum evaporator at 60°C for 30 min. Then, the oil was heated in an oven at 60°C for 2 h. The oil extraction efficiency was calculated as the percentage of weight of the oil to the content of oil in soybean flour [14].

2.4. Mass Transfer Model for Oil Extraction. Extracting soybean oil by AOT reverse micelle was a typical solid-liquid extraction involving the transfer of the oil from solid to the liquid phase. According to Fick's Law, the first order of solid-liquid extraction shrinking nucleus model was as follows [19]:

$$\frac{\delta}{3D_1}x + \frac{r_0}{2D_s} \left[1 - \frac{2}{3}x - (1-x)^{2/3} \right] + \frac{1}{k_r} J \left[1 - (1-x)^{1/3} \right] = \frac{bC_{A0}}{\alpha\rho_B r_0} t, \quad (1)$$

where t is extraction time (min), x is extraction rate of soybean oil, a , b is stoichiometric constant, δ is thickness of reaction region (cm), ρ_B is solid reactant density (g/cm³), r_0 is radius of solid reactant (cm), C_{A0} is fluid mass concentration (g/cm³), D_l is effective diffusion coefficient when the liquid reactant get through the liquid boundary layer (cm²/min), k_r is constant reaction rate of interface chemical reaction (cm²/s), and D_s is effective diffusion coefficient when the liquid reactant get through the solid boundary layer (cm²/min)

When the extraction rate is controlled by internal diffusion of the soybean flour, the Fick Law can be simplified as follows:

$$1 + 2(1 - x) - 3(1 - x)^{2/3} = \frac{6bD_s C_{A0}}{\alpha \rho_B r_0^2} t. \quad (2)$$

When the extraction rate is controlled by the external diffusion of the boundary layer, the Fick Law can be simplified as follows:

$$x = \frac{3bD_1 C_{A0}}{\alpha \delta \rho_B r_0} t. \quad (3)$$

When the extraction rate is controlled by the interfacial reaction, the Fick Law can be simplified as follows:

$$1 - (1 - x)^{1/3} = \frac{bk_r C_{A0}}{\alpha \rho_B r_0} t. \quad (4)$$

2.5. Character Determination of Soybean Oil and Protein

2.5.1. Analysis of Soybean Oil Properties. Oil content of soybean flour was determined by Soxhlet extraction [20]. Acid value (AV), peroxide value (POV), fatty acid composition, color, and phospholipid content were determined according to the standard methods of the International Union of Pure and Applied Chemistry for analysis of oils and fats.

2.5.2. FTIR Analysis of Soybean Protein. Infrared spectra were obtained using a WQF-520 infrared spectroscope (Beijing Beifen-Ruili Analytical Instrument Co., Ltd., Beijing, China). Proteins (2 mg) were mixed with KBr (1:100 w/w) and tableted. Scanning wavelength ranges were 4000–400 cm^{-1} with resolution of 4 cm^{-1} . The results were analyzed using Origin 8.5 and PeakFit software [21].

2.5.3. Amino Acid Composition of Soybean Protein. The amino acid content of soybean proteins was determined by S433D amino acid analyzer (Sykam Co., Ltd., Germany) according to the method of Pietrysiak with some modification [22]. Proteins (10 mg) were hydrolyzed in 10 mL 6 mol/L HCl containing 3–4 drops phenol at 110°C for 22 h. Hydrolysate thus produced was filtered and its volume brought up to 50 mL with distilled water. Take 1 mL hydrolysate and dried by N_2 . Redissolve the above dried sample and dry again. This procedure was repeated twice. The dried sample was then dissolved in 1 mL buffer (pH 2.2). Finally, the solution was filtered through a 0.22 μm membrane. For analysis, 50 μL was injected into the analyzer. Proline was detected at a wavelength of 440 nm, and the remaining amino acids were detected at 570 nm.

2.6. Statistical Analysis. All measurements were carried out in triplicate. The data was submitted to one-way analysis of variance (ANOVA) using SPSS 8.0 software. All figures were created using Origin 8.5 software.

3. Results and Discussion

3.1. Factors Affecting Efficiency of Soybean Oil Extraction

3.1.1. Oscillating Speed. The effect of oscillating speed on the efficiency of soybean oil extraction was evaluated at 40 min of extraction time and a solid/liquid ratio of 0.005 g/mL. Efficiency increased from 78.06% to 91.10% with oscillating speed range of 0–60 r/min ($P < 0.05$) (Figure 2(a)); however, efficiency did not change significantly when the oscillating speed rose above 60 r/min ($P > 0.05$). This was similar to results of Nguyen et al. [23]. The increase in efficiency at speeds below 60 r/min could be due to increasing diffusion of soybean flour. At a speed of 60 r/min, maximum of extraction rate had been reached, so increasing speed had little influence on the extraction of oil by AOT reverse micelle system.

3.1.2. Solid/Liquid Ratio. The effect of solid/liquid ratio on the oil extraction efficiency was shown in Figure 2(b). The ratio was varied from 0.005 to 0.035 g/mL, and extraction time was 40 min at the oscillating speed of 60 r/min. The efficiency of soybean oil extraction decreased from 92.13% to 78.59% with the increase of solid/liquid ratio from 0.01 to 0.035 g/mL. The highest extraction efficiency was observed at 0.01 g/mL. The oil extraction efficiency decreased at higher solid/liquid ratios likely because the viscosity increase made it difficult to maintain effective mixing [24]. Lower solid/liquid ratio is required to provide good solution contact with the solids and ample capacity for the extracted oil [23]. However, too low of a solid/liquid ratio causes less particle collision, leading to poor extraction efficiency [24].

3.1.3. Surfactant Concentration. Surfactant used in extraction is able to produce ultralow interfacial tension between the surfactant solution and oils in order to liberate the oil from the seed [24]. Figure 2(c) showed the effect of surfactant concentration on the extraction efficiency of oil. The efficiency of oil extraction increased from 85.00% to 95.30% when the surfactant concentration increased up to 0.12 g/mL. However, there were no obvious differences in extraction efficiency when the surfactant concentration rose above 0.10 g/mL ($P > 0.05$). Similar results were observed by previous researches [24, 25]. The surfactant concentration affected the molar ratio of water to surfactant (W_0) and the number of reverse micelles, which are important elements related to extraction efficiency of oil and protein in the AOT reverse micelle system [8, 25]. Furthermore, surfactant solution can reach equilibrium interfacial tension with oils at certain concentration and extraction time [24].

3.1.4. Extraction Time and Temperature. After 30 min of extraction, 89.59% oil was extracted (Figure 2(d)). For a longer time of 70 min, the oil extraction efficiency was statistically the same as that obtained at 30 min ($P > 0.05$). This result could be due to the rapid mass transfer for the AOT reverse micelle extraction process, a balance being attained between isooctane and oil over a period time of 30 min. With regard to temperature, oil extraction efficiency of soybean oil increased from 83.10% to 90.29% as the temperature

FIGURE 2: Effects of various factors on the extraction efficiency of soybean oil: (a) oscillating speed; (b) solid/liquid ratio; (c) surfactant concentration; (d) extraction time; (e) extraction temperature; (f) particle size of soya bean flour. *Note.* Different small letters (A–D) mean significant difference at $P < 0.05$.

TABLE 1: Reaction rate constant at different temperatures.

Control step	T/K	293	303	313	323	333
$1 + 2(1 - x) - 3(1 - x)^{2/3} = K_1 t$	K_1	0.021	0.023	0.025	0.027	0.028
$1 - (1 - x)^{1/3} = K_2 t$	K_2	0.022	0.023	0.024	0.025	0.026

TABLE 2: The experimental and calculated value.

Extraction time (min)	26°C			34°C			41°C		
	Experimental value (%)	Calculated value (%)	Relative error (%)	Experimental value (%)	Calculated value (%)	Relative error (%)	Experimental value (%)	Calculated value (%)	Relative error (%)
5	47.02	50.25	6.43	48.11	51.57	6.71	48.25	52.62	8.30
10	65.81	66.47	0.99	66.95	68.06	1.63	68.38	69.29	1.31
15	78.25	77.02	1.60	79.87	78.66	1.54	81.04	79.92	1.40
20	84.63	84.57	0.07	85.77	86.15	0.44	86.89	87.18	0.33

increased from 30°C to 60°C; however, the oil yield remained constant with further increases in temperature ($P > 0.05$). The extraction efficiency was as high as 90.29% at 60°C (Figure 2(e)). The density of the organic solvent reduced with increasing temperature and resulted in the decrease of oil solubility. Similar yield trend as a function of temperature was observed in the extraction of other materials [26].

3.1.5. Particle Size. Particle size played an important role in the oil yield. Figure 2(d) showed the relationship between particle size and extraction efficiency of oil. The results showed that greater extraction efficiency was observed in smaller particles (100 mesh). The extraction efficiency remained constant while particle size was below 80 mesh. This result was consistent with the research of Do et al. [27]. This can be due to increased specific surface area with smaller particles and accessibility of disrupted cells on the particle surface [27]. In addition, the smaller the particle size, the shorter the mass transfer distance of oil in soybean particle interior, and this decreases the internal mass transfer resistance of oil and does help to increase the extraction efficiency [17, 26].

3.2. Mass Transfer Model for Oil Extraction by AOT Reverse Micelle. Oil extraction efficiency of soybean oil showed no obvious change after 20 min (Figure 2(d)). This might indicate that the mass transfer of soybean oil was in the first 20 min of extraction. Besides, the extraction efficiency did not vary significantly between 60 and 120 r/min. This pattern suggests that external diffusion has little influence on the extraction of oil using the AOT reverse micelle system.

The effect of temperature on the extraction efficiency of soybean oil was shown in Figure 3(a). Significant increasing of extraction efficiency was observed before 20 min. The fitting equation obtained from internal ($y = 1 + 2(1 - x) - 3(1 - x)^{2/3}$) and interfacial reaction ($y = 1 - (1 - x)^{1/3}$) was shown in Figures 3(b) and 3(c), and the extraction rate constant was expressed as K_1 and K_2 , respectively (Table 1).

The apparent activation energy of extraction process can be calculated by Arrhenius equation as follows:

$$K = Ae^{E/RT}, \quad (5)$$

where A is the frequency factor, E is the apparent activation energy, R is the gas constant 8.314 J/(mol·K), and T is thermodynamic temperature.

Log both sides and the equation becomes the following:

$$\ln K = \ln A - \frac{E}{RT}. \quad (6)$$

According to Figure 3(d), the apparent activation energy was calculated as 5.99 and 3.39 kJ/mol of internal diffusion and interfacial reaction, respectively. Previous researchers have reported that the apparent activation energy is always 8–20 kJ/mol when it is an internal diffusion reaction and at 42–420 kJ/mol when as interfacial reaction [17]. Thus, it can be concluded that the oil extracted by AOT reverse micelle system was under the control of internal diffusion.

3.3. Model Building and Verification. According to the experimental results above, the soybean oil extracted by AOT reverse micelle system was under the control of internal diffusion and the apparent activation energy was 5.99 kJ/mol. The mass transfer model can be set up as follows:

$$1 + 2(1 - x) - 3(1 - x)^{2/3} = 0.248 \cdot \exp\left(-\frac{720.8}{T}\right) \cdot t. \quad (7)$$

The compliance test was done at 26°C, 34°C, and 41°C. The relative error of the experimental and calculated value was no more than 1.6% except extraction of 5 min (Table 2). These results indicated that the experimental and calculated values matched well. So, the mass transfer model of the soybean oil extracted by AOT reverse micelle is $1 + 2(1 - x) - 3(1 - x)^{2/3} = 0.248 \cdot \exp(-720.8/T) \cdot t$.

FIGURE 3: The extraction kinetic curves of SPI by AOT reverse micelle: (a) effect of temperature to the extraction efficiency; (b) the extraction kinetic curve by equation $1 + 2(1-x) - 3(1-x)^{2/3} = K_1 t$; (c) the extraction kinetic curve by equation $1 - (1-x)^{1/3} = K_2 t$; (d) the apparent activation energy curve of SPI extraction by AOT reverse micelle.

3.4. Characteristics of Soybean Oil and Protein

3.4.1. Physicochemical Properties of Soybean Oil. The oil characteristics were evaluated by color, acid value (AV), peroxide value (POV), vitamin E (V_E) content, phospholipid content, composition of fatty acid, and triglyceride content. The physicochemical properties of oil extracted by AOT reverse micelle and Soxhlet were shown in Table 3. Compared to Soxhlet extracted oil, the oil extracted by AOT reverse micelle system has lighter color and lower AV and POV values (Table 3). Meanwhile, phospholipid content in AOT reverse micelle extracted oil (1.11%) was lower than that in Soxhlet extracted oil (2.80%). The organic reagent used with Soxhlet dissolves not only phospholipids but also some organic pigments. That explains the darker color of the oil

extracted by Soxhlet. However, the V_E content in oil extracted by the two methods had no distinct differences ($P > 0.05$).

As can be seen in Table 3, the fatty acid percentages of the two kinds of oil showed no obvious differences. This announced the feasibility of the AOT reverse micelle extraction. Triglyceride percentage composition of the two kinds of oil echoes a former study which found that the oil extracted by Soxhlet was readily developed in that the triacylglycerol turned into diglycerides, monoglycerides, and free fatty acid. Due to this, the free fatty acid of Soxhlet extracted oil was higher than that of oil extracted by AOT reverse micelle (Table 3).

3.4.2. FTIR Analysis of Soybean Protein. The secondary structure properties of soybean protein extracted by AOT reverse

TABLE 3: The characteristics of soybean oil extracted by different methods.

Extraction method	Color		AV (KOHmg/g)	POV (mmol/kg)	V _E (mg/100 g)	Phospholipid content (%)	Fatty acid composition (%)				Triglyceride percentage composition (%)				
	Yellow	Red					Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	MAG	DAG	TAG	FFA
SBO1	46.00±1 ^a	3.10 ± 0.1 ^a	3.06 ± 0.05 ^a	8.75 ± 0.10 ^a	31.57 ± 0.20 ^a	2.80 ± 0.10 ^a	10.86	5.41	22.87	52.64	8.22	0.66	1.79	96.04	1.52
SBO2	30.00±1 ^b	1.90 ± 0.1 ^b	1.04 ± 0.05 ^b	3.35 ± 0.10 ^b	30.21 ± 0.20 ^a	1.11 ± 0.10 ^b	10.80	5.31	22.74	52.82	8.31	1.29	3.04	95.16	0.52

Note. SBO1: soybean oil obtained by Soxhlet extraction; SBO2: soybean oil obtained using AOT reverse micelle extraction method; AV: acid value; POV: peroxide value; MAG: monoacylglycerols; DAG: diacylglycerols; TAG: triglyceride; FFA: free fatty acid. Different small letters (a-b) mean significant difference at $P < 0.05$.

FIGURE 4: The FTIR spectra of SPI extracted by different extraction methods: (a) soybean protein isolate obtained using alkali-solution and acid-isolation method; (b) soybean protein isolate obtained using AOT reverse micelle extraction method.

micelle were investigated by FTIR, and comparative studies of soybean protein (AOT reverse micelle and alkali-solution and acid-isolation methods) were also observed. According to FTIR absorption spectra, the most important band regions of amide I and amide II were in $1800\text{--}1400\text{ cm}^{-1}$. The amide I region $1700\text{--}1600\text{ cm}^{-1}$ is commonly used for the evaluation of protein secondary structures. This absorption originates from C=O stretching and N-H vibration. The amide II region between 1600 and 1500 cm^{-1} is dominated by chain oscillations. It mainly contains the N-H in-plane bending and the C-N stretching vibration of the backbone [28].

The region from 1660 cm^{-1} to 1650 cm^{-1} was assigned as α -helix [29]. The band in alkali-solution and acid-isolation method was located at 1655 cm^{-1} and that in AOT reverse micelles was at 1656 cm^{-1} according to Figure 4. The regions $1610\text{--}1640\text{ cm}^{-1}$ and $1670\text{--}1680\text{ cm}^{-1}$ represented the absorption of a β -sheet structure [29]. In this study, we assigned the β -sheet absorption in the region of $1610\text{--}1640\text{ cm}^{-1}$ and the region of $1660\text{--}1700\text{ cm}^{-1}$ to a turn structure. Meanwhile, the band in $1650\text{--}1640\text{ cm}^{-1}$ was assigned to an unordered structure. The absorption of protein extracted by AOT reverse micelle in these regions has a slight displacement to the high field (Figure 4).

The quantitative analysis of soybean protein secondary structures is shown in Table 4. Compared to alkali-solutions and acid-isolation method, turn and unordered structure percentages decreased with AOT reverse micelle extraction, while the percentage of β -sheet structure increased. Meanwhile, α -helix structure in soybean protein as determined by AOT reverse micelles was slightly decreased (Table 4). This result indicates that the denaturation of protein by AOT reverse micelle extraction is less than that by alkali-solution and acid-isolation method. However, this was opposite to the result of Chen, whose results indicate that the secondary structure of soy protein might be partly destroyed in AOT reverse micelle [21]. Changes in the secondary structures

TABLE 4: Content of the secondary structure in different varieties of soybean protein by FTIR analysis.

Extraction soybean protein	Secondary structure (%)			
	A-Helix	β -Sheet	Unordered	Turn
SP1	12.90	39.10	13.14	34.86
SP2	12.12	41.86	12.64	33.38

Note. SP1: soybean protein obtained using alkali-solution and acid-isolation method; SP2: soybean protein obtained using AOT reverse micelle extraction method.

of soybean protein might have an effect on its functional properties; we will investigate this possibility in our further research.

3.4.3. Amino Acid Analysis of Soybean Protein. The amino acid content in soybean proteins was obtained using Clarity Amino software by amino acid analyzer. The test results for the 8 essential amino acids found in the soybean proteins are shown in Table 5. Extraction methods had no effect on the amino acid composition. The contents of aspartic acid, serine, threonine, glutamate, cysteine, glycine, and lysine were slightly higher in soybean protein extracted by AOT reverse micelle than in that extracted by alkali-solution and acid-isolation method. However, there were no significant differences in the composition of amino acids between the soybean proteins extracted by the two methods.

Amino acids were a main component and nutrient of soybean protein and have an important effect on the nutrition, function, and structural properties of protein. Comparing to alkali-solution and acid-isolation protein, polar amino acids content increased in AOT reverse micelle extracted protein (Table 5). The content of threonine, serine, glycine, and lysine in AOT reverse micelle extracted protein was 3.66%, 4.80%, 4.02%, and 6.75%, respectively. The characteristics of amino acids might lead to better solubility of AOT reverse micelle extracted protein. Changes in protein structure might result in the alterations of functional properties of protein, and such changes would be of vital importance to its uses in the food industry [30].

4. Conclusion

The extraction of oil and protein by AOT reverse micelle was studied. The most efficient soybean oil extraction was reached at oscillation speed 60 r/min, solid/liquid ratio 0.005 g/mL, AOT concentration 0.10 g/mL, temperature 60°C , and extraction time 30 min. The results showed that the mass transfer of the oil extracted occurred by internal diffusion. The mass transfer model can be set up as $1 + 2(1 - x) - 3(1 - x)^{2/3} = 0.248 \cdot \exp(-720.8/T) \cdot t$. The physicochemical properties of oil indicated that oil extracted by AOT reverse micelle had better quality than by Soxhlet extraction. Meanwhile, the fatty acid percentage and composition of oil extracted by AOT reverse micelle did not differ significantly from that obtained by Soxhlet extraction. According to FTIR spectroscopy, the soybean protein retained almost entirely its original structure when extracted by AOT reverse micelle. The amino acid

TABLE 5: Amino acid content (%) of soybean protein extracted by different methods.

Extraction method	Aspartic acid	Threonine	Serine	Glutamate	Glycine	Alanine	Cystine	Valine	Methionine	Isoleucine	Leucine	Tyrosine	Phenylalanine	Lysine	Histidine	Arginine	Proline
SP1	11.21	3.59	4.76	19.93	3.92	4.13	1.81	4.98	1.27	4.70	8.01	3.49	5.62	6.54	2.88	8.40	4.77
SP2	11.90	3.66	4.80	21.48	4.02	3.86	2.28	4.35	1.00	4.42	7.11	3.47	5.28	6.75	2.81	8.42	4.40

Note. SP1: soybean protein obtained using alkali-solution and acid-isolation method; SP2: soybean protein obtained using AOT reverse micelle extraction method.

composition of protein extracted with AOT reverse micelle was similar to that with alkali-solution and acid-isolation method. The results of this study provide an important theoretical basis for simultaneous extraction of soybean oil and protein by AOT reverse micelle system.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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