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Dietary Fiber Extraction from Soy Sauce Residue

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Abstract. Dietary fiber was extracted from soy sauce residues by enzyme treatment and alkali solution. The effects of extraction temperature, concentration of alkaline, ratio of material to solution and **extraction** time on extraction yield were investigated. The extraction conditions were optimized by $L_9(3^4)$ orthogonal design. The results showed that the optimal conditions were under extraction temperature 80°C, the concentration of alkaline 4%, the extraction time 30 min, and solid-liquid ratio 1:12, which led to the yield as high as 65.31%. The water capacity of insoluble dietary fiber is 5.14 g/g, and swelling capacity of insoluble dietary fiber is 5.46 mL/g.

Keyword: soy sauce residue, dietary fiber, orthogonal design

1. Introduction

Dietary fiber is plant-based ingredient which includes polysaccharides and lignin that unable to be digested and absorbed by small intestinal [1]. According to the solubility in water quality, dietary fiber is divided into soluble dietary fiber (SDIETARY FIBER) and insoluble dietary fiber (IDIETARY FIBER). Previous studies had shown that it had holding water capacity, holding oil capacity and adsorbing metal ions capacity, which has an important regulatory effect on the human body blood sugar and blood lipid metabolism [2]-[5].

Soy sauce residue is the byproducts during the production of soy sauce. The soy sauce residue is rich in fiber, lignin and protein [6]. The soy sauce residue is often used as feed to animals, however its acceptability to animals is lower because of its high salt content [7]. The exploration on soy sauce residue is necessary so as to improve its utilization value. The objective of this paper is to extract dietary fiber from soy sauce residue[8]. Further, the optimal extraction conditions were investigated.

2. Materials and Methods

2.1. Materials

Soy sauce residue was kindly provide by Guangzhou Meiweixian Seasoning Lt. Company (Guangzhou, China). Sodium hydroxide, absolute ethyl alcohol, concentrated hydrochloric acid were of chemical grade. Supercritical carbon dioxide extraction plant was obtained from Shenyang Supercritical Fluid Extraction Equipment (Shenyang, China). Microwave oven (WD900B) was obtained from Galanz Electrical Appliances (Foshan, China).

2.2. Extraction Yield

Extraction yield was calculated as follows:

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$$\text{Dietary fiber extraction yield}(\%)=\frac{A_1}{A}\times 100\%$$

where A_1 was weight of dietary fiber from sample, and A was dry basis weight of the sample.

2.3. Swelling Capacity

Dietary fiber was accurately weighted as 1.00 g, put it in 10mL graduated cylinder. An aquilot of 10.00 mL distilled water in the measuring cylinder was performed by fully oscillation and kept at room temperature for 24 h. The volume of dietary fiber was determined before and after the swelling, with the swelling calculated as follows:

$$\text{Swelling Capacity}(mL/g)=\frac{V_1-V_0}{A}$$

where V_1 was the volume after the swelling, V_0 was the volume before the swelling, and A was dry basis weight of the sample.

2.4. Holding Water Capacity

Dietary fiber was accurately weighted as 1.00 g, put in 100 ml beaker, added distilled water 75ml, followed by stirring at 25°C for 2 h, then transfer it to the centrifugal glass and centrifuged at 3000 rpm for 0.5 h. Supernatant was poured, dried and weighted.

$$\text{holding water capacity}(g/g)=\frac{A_1-A}{A}$$

where A_1 was the sample weight after absorbing water ,and A was dry basis weight of the sample.

3. Result

3.1. Factors Influencing Extraction Yield

3.1.1. Sodium hydroxide concentration effects on dietary fiber extraction yield

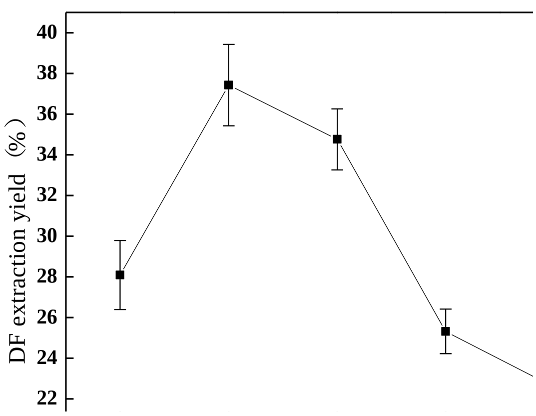

Fig. 1: NaOH concentration effects on dietary fiber extraction yield

As shown in Figure 1, with the concentration of NaOH solution increased gradually, the dietary fiber extracted yield increases firstly and then decreases. When the concentration of NaOH solution was 4%, dietary fiber extraction yield reached up to 37.21%. In this study, 2%~6% was selected as the NaOH concentration factor levels orthogonal experiment.

3.1.2. Extraction temperature effects on dietary fiber extraction yield

As shown in Figure 2, with the increase of extraction temperature, the dietary fiber extracted yield increases firstly and then decreases. When reaching up to 80°C, the maximum value (over 80°C) was obtained, and extraction yield began to drop sharply. If the temperature was too high, the reaction became more and more intense, accelerating cellulose decomposing. In this study, 60°C~80°C was selected as orthogonal experiment of extracting temperature factor level.

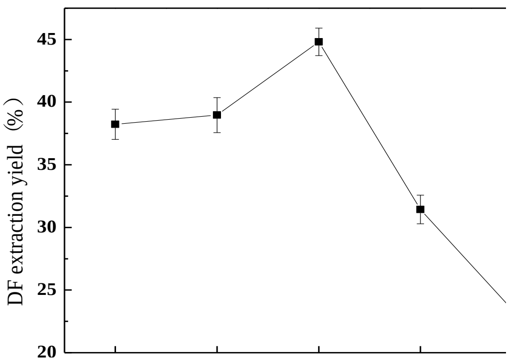

Fig. 2: Effects of extraction temperature on dietary fiber extraction yield

3.1.3. Extraction time effects on dietary fiber extraction yield

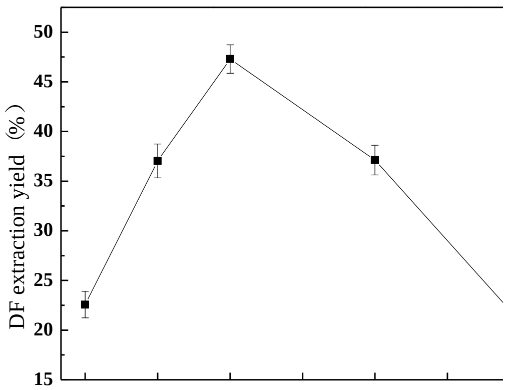

Fig. 3: Effects of extraction time on dietary fiber extraction yield

As shown in Figure 3, along with the increase of extraction time, the dietary fiber extracted yield increases firstly and then decreases, when extraction time reached 60 min to reach the maximum value. After extracted for 60 min, the extracted yield began to fall. Because the longer reaction time, the more cellulose decomposed. This study chose 30min~60min as orthogonal experiment of extracting time factor levels.

3.1.4. Extraction of solid-liquid ratio effects on the dietary fiber extraction yield

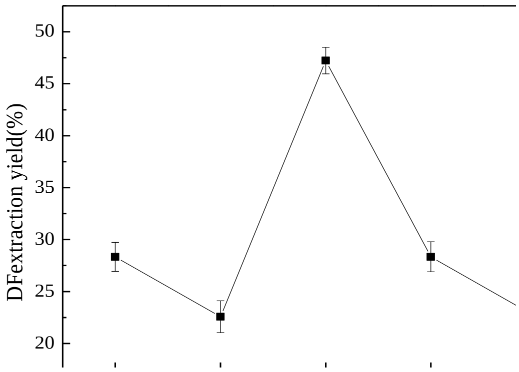

Fig. 4: Effects of solid-liquid ratio on dietary fiber extraction yield

As shown in Figure 4, along with the decrease of solid-liquid ratio, the dietary fiber extraction yield increases firstly and then decreases. When solid-liquid ratio was 1:15, the maximum value of extraction yield were attained. This study chose 1:10~1:15 as orthogonal test than the factors of material liquid level.

3.2. Orthogonal Experiment

On the basis of single factor experiment, this study determined by NaOH concentration, extraction temperature, extraction time and solid-liquid ratio as variables factors in $L_9(3^4)$ orthogonal test. Dietary fiber extraction yield was chosen as dependent variable to evaluate the best extraction technology conditions, factor level as shown in Table I.

Table I: Orthogonal experiment design of dietary fiber extraction conditions

Num	concentration (%)(A)	temperature（°C）(B)	time（min）(C)	solid-liquid ratio（g/mL）(D)
1	2	60	30	1:10
2	4	70	45	1:12
3	6	80	60	1:15

The orthogonal experiment of results and analysis are shown in Table II. Triplicate parallel tests were performed and the average value was calculated.

Table II: Orthogonal test table

Num.	A	B	C	D	Dietary fiber extraction yield
1	1	1	1	1	27.89
2	1	2	2	2	48.08
3	1	3	3	3	51.60
4	2	1	2	3	30.16
5	2	2	3	1	45.48
6	2	3	1	2	65.31
7	3	1	3	2	27.65
8	3	2	1	3	44.69
9	3	3	2	1	44.26

("※"means $p<0.05$ "※※"means $p<0.01$）

Within the scope of selected factor, extraction temperature reached the significant level, and the concentration of alkali solution reached significant level, while the other two factors was not significant. Primary and secondary order of factor extraction is temperature > concentration > solid-liquid ratio > extraction time.

Table III: The optimal level of lye concentration

alkali concentration（%）	mean	SER	95% confidence interval	
			lower limit	upper limit
2	0.425	0.021	0.38	0.47
4	0.47	0.021	0.425	0.515
6	0.389	0.021	0.344	0.433

Table IV: The optimal level of extraction temperature

Extraction temperature（°C）	mean	SER	95% confidence interval	
			lower limit	upper limit
60	0.286	0.021	0.241	0.33
70	0.461	0.021	0.416	0.506
80	0.537	0.021	0.492	0.582

Table V: The optimal level of extraction time

Extraction time（min）	mean	SER	95% confidence interval	
			lower limit	upper limit
30	0.46	0.021	0.415	0.504
45	0.408	0.021	0.364	0.453
60	0.416	0.021	0.371	0.461

Table VI: The optimal level of solid-liquid ratio

solid-liquid ratio（g/mL）	mean	SER	95% confidence interval	
			lower limit	upper limit
1:10	0.392	0.021	0.347	0.437
1:12	0.47	0.021	0.425	0.515
1:15	0.422	0.021	0.377	0.466

According to the orthogonal experiment results (Table III-Table VI), the optimal level of various factors: (1) the optimal level of NaOH solution concentration is 4%; (2) the optimal level of soaking temperature is 80°C; (3) the optimal level of extraction time is 30 min; (4) the optimal level of solid-liquid ratio is 1:12. In summary, the optimal extraction level combination is A2B3C1D2, consistent with the experimental result of the sixth group. The purity of product reached up to 92.3%.

3.3. Swelling Capacity and Holding Water Capacity of Dietary Fiber

According to the orthogonal test to determine the optimum extraction conditions, holding water capacity of the insoluble dietary fiber was 5.14 g/g, and swelling capacity of the insoluble dietary fiber was 5.46 mL/g.

4. Discussion

By single factor and orthogonal experiments in this study, the optimum conditions was determined to be NaOH concentration 4%, soaking temperature 80°C, extraction time 30 min and solid-liquid ratio 1:12, total dietary fiber extraction yield was 65.31%. The holding water capacity of insoluble dietary fiber is 5.14 g/g, and swelling capacity of insoluble dietary fiber is 5.46 mL/g.

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