 https://doi.org/10.1051/e3sconf/202018902015

Study on the Technology of Extracting Water-soluble Dietary Fiber (SDF) from Peanut Shell by Ultrafine Grinding and Microwave

Yitong Gong[1*]

[1]Ludong University, 264000, China

Abstract. Using ultra-fine pulverized peanut shells as raw materials, the effects of citric acid mass fraction, microwave processing time, and microwave power on the extraction rate of SDF were investigated. The box-Behnken experimental design and response surface analysis method were used to optimize the microwave-assisted ultra-fine pulverization. The SDF process for extracting peanut shells determines the best extraction conditions. The optimal extraction conditions for SDF are that citric acid mass fraction is 4.2%, microwave treatment time is 4.5min, microwave power is 400W and material-liquid ratio is 1:30. The yield and the purity of SDF is respectively 47.05% and 85.35%.

1 INTRODUCTION

Dietary fiber is the "seventh major nutrient" necessary for human health. It is divided into two categories: watersoluble dietary fiber (SDF) and insoluble dietary fiber (IDF) according to solubility. SDF has better physiological functions than IDF, which not only plays an important role in the prevention of certain diseases (cardiovascular disease, diabetes), detoxification, and lipid lowering, but also is used as a food additive in bakery foods, beverages, dairy products and ice cream, etc[1]. The dietary fiber content in peanut shells is as high as 65.7%-79.3%. As a cheap and easily available raw material for producing dietary fiber, it has good economic and social benefits [2].

China is the world's largest producer of peanuts, with an annual output of nearly 4000 kt of peanut shells, which are rich in dietary fiber. Except for a small part of these peanut shells are used as feed and edible fungus culture medium, most of them are thrown away, resulting in a great waste of resources. For the extraction methods of SDF in peanut shells, there are reports on microwave method, such as ultrasonic method, acid method, alkali method, enzymatic method, etc[3]. Among them, the enzymatic extraction rate is high, but the process is unstable and expensive, which is not suitable for industrialized large-scale production. The ultrafine pulverization method is rarely reported. In this paper, the samples were processed by the ultrafine pulverization method, and the microwave combined with the acid method was used to extract SDF. The ultrafine pulverization microwave-assisted acid method peanut shell SDF extraction process was studied, and an efficient and novel peanut shell SDF extraction process was explored.

2 MATERIALS AND METHODS

2.1 Test reagent and equipment

Wash crushed peanut shells, citric acid, α-heat-resistant amylase, protease, amyloglucosidase, diatomaceous earth, disodium hydrogen phosphate, sodium dihydrogen phosphate, sodium hydroxide, hydrochloric acid, acetone. DE-200 Rhodiola universal high-speed grinder, WJW400 superfine grinder, DZF-6020 freeze drying oven, DK-S24 electric heating constant temperature water bath, WBFY-205 microcomputer microwave chemical reactor, ZA220R4 analytical balance , SHB circulating water multipurpose vacuum pump, RE-52AA type rotary evaporator, TGL20M desktop high-speed refrigerated centrifuge.

2.2 SDF extraction method

Affiliations of authors should be typed in 9-point Times. They should be preceded by a numerical superscript corresponding to the same superscript after the name of the author concerned. Please ensure that affiliations are as full and complete as possible and include the country.
Fresh peanut shells was washed, soaked in 2% $NaHCO3$ solution, stirred intermittently, then washed and dried. The dry peanut shells were crushed with a high-speed universal crusher. The 2g peanut shell superfine powder in a beaker added a certain amount of distilled water and a certain mass fraction of citric acid solution, was treated with microwave and centrifuged to take the supernatant, which was concentrated to about 1/4 with a rotary evaporator. Then SDF was obtained through 4 times the

* Corresponding author: 402352522@qq.com

 https://doi.org/10.1051/e3sconf/202018902015

volume of absolute ethanol was added to the concentrated solution refrigerated overnight.
SDF yield calculation [4]: SDF yield (%)=SDF quality/sample quality*100%

In order to determine the process conditions, the effects of citric acid mass fraction, microwave power, and microwave extraction time on the yield of SDF were studied separately. The single factor test factors and levels are shown in Table 1.

2.3 Single factor experimental design

Table1 Factors and levels of single factor experiment

Level/factor	Mass fraction of citric acid /%	Microwave time /min	Microwave power/W	Material to liquid
1	1	2	100	1:10
2	2	4	250	1:20
3	3	6	400	1:30
4	4	8	550	1:40
5	5	10	700	1:50

Table2 Factors and levels used in Box-Behnken experimental design

factor	-1	0	1
Mass fraction of citric acid /%	3	4	5
Microwave power/W	250	400	550
Microwave time /min	2	4	6

2.4 Response surface test design

According to the Box-Behnken experimental design principle and the single-factor experiment results, select the mass fraction of citric acid (A), microwave power (B), and microwave processing time (C) Three factors are used for response surface testing as shown in Table 2.

3 RESULTS AND ANALYSIS

3.1 The influence of various test factors on the yield of SDF

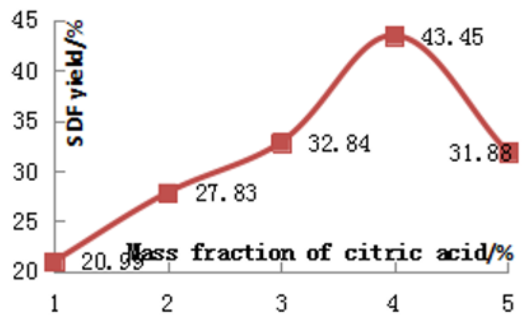


Fig.1 Effect of citric acid content on SDF

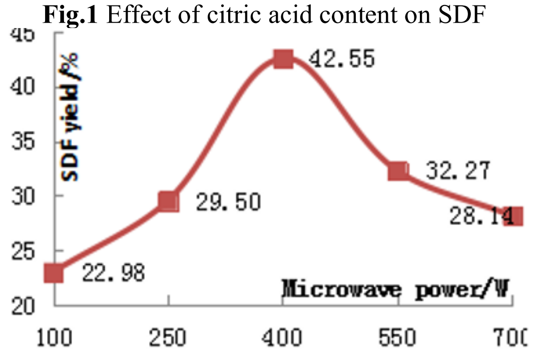


Fig. 2 Effect of microwave power on SDF

The yield of SDF firstly increases with the increase of the mass fraction of citric acid. When the mass fraction of citric acid is 4%, the yield of SDF reaches the highest value of 43.45%, then the yield of SDF decreases, as shown in Figure 1. It may be due to the fact that when the concentration of citric acid is too small, the dissolution of SDF is insufficient. When the concentration of citric acid is too large, it may change the ingredients in the raw materials and hinder the precipitation of SDF. Therefore, the mass fraction of citric acid is selected as 4%.

As the microwave power goes from 100w to 700w, the SDF extraction rate firstly increases and then decreases. When the microwave power is 400w, the yield is the highest,which is 42.55%, as shown in Figure 2. Microwave power mainly affects the heating speed. The higher the microwave power, the more microwave energy the extract system absorbs, which speeds up diffusion speed and is beneficial to the dissolution of ingredients. However, excessive power leads to excessively high temperature. Microwave power of 400W is selected.

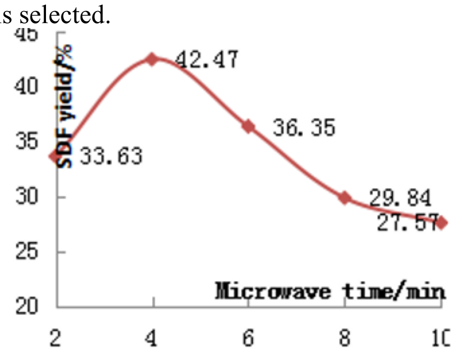


Fig.3 Effect of microwave time on SDF

 https://doi.org/10.1051/e3sconf/202018902015

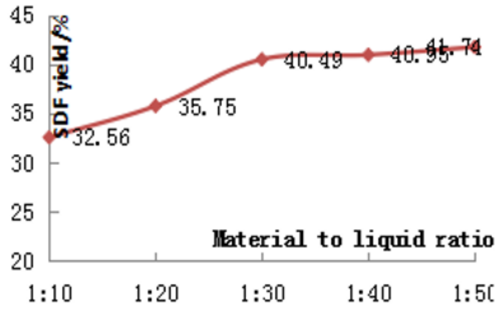


Fig. 4 Effect of ratio of material-liquid on SDF

SDF extraction rate increases with the extension of time, from 4min to 10min, the SDF extraction rate decreases with the extension of time, the SDF extraction rate is the largest at 4min, which is 42.47%, as shown in Figure 3. When microwave treatment time is short, the solvent's dissolving power is weak. When treatment time is too long, the damage to the cell wall has reached the maximum and the solvent dissolving capacity has also reached saturation. The microwave processing time is 4min.

The material-liquid ratio ranges from 1:10-1:50. With the increase of the material-liquid ratio, the extraction rate of SDF shows an upward trend, reaching the maximum at 1:50, which is 41.7%, as shown in Figure 4. With the increasing of material-to-liquid ratio, there is sufficient solvent to dissolve SDF, which is beneficial to the dissolution of SDF. The material-to-liquid ratio is 1:30 because of economic.

3.2 Response surface method to optimize extraction process of SDF

According to the single factor test results, the citric acid mass fraction (A), microwave power (B), microwave processing time (C), and 3 factors are used as independent variables. According to the Box-Behnken test scheme, A three-factor and three-level response surface analysis test was carried out[5]. The experimental design and results are shown in Table 3.

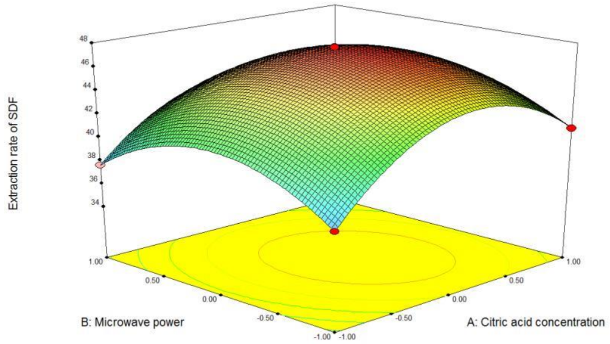
Table 3 Box-Behnken test design and results

Test number	Mass fraction of citric acid /%	Microwave power/W	Microwave time/s	SDF yield/%
1	1	1	0	45.00
2	-1	-1	0	42.01
3	0	0	0	47.67
4	-1	0	1	37.66
5	0	0	0	46.90
6	1	0	-1	40.87
7	0	0	0	47.14
8	0	0	0	47.65
9	1	-1	0	37.25
10	0	-1	1	39.02

The peanut shell SDF yield (Y) was obtained through the data performed 2 times multiple regression by Design Expert 8.0.6 software. The citric acid mass fraction (A), microwave power (B), microwave processing time (C) The second-order polynomial regression equation between) is: Y=47.41+1.12A-0.49B+0.38C-0.57AB+3.50 AC+1.40BC-5.00A2-3.72B2-2.40C2. It an draw a conclusion from the equation that the influence of the three factors on the response value (SDF extraction rate), citric acid mass fraction (A) > microwave power (B) > microwave processing time (C).

The response surface diagram and contour diagram are made through interaction analysis of the three factors of citric acid mass fraction (A), microwave power (B) and microwave processing time (C).

It' s intuitively found that the influence of various factors on the response value were different from the response surface diagram. The steeper the curve, the greater the influence of the factor on the response value, and the smoother the curve, which means the smaller the influence of the factor on the response value. The order of influence of various factors on the yield of SDF shown in response surface diagram of Figures 5-7 is as follows, citric acid mass fraction> microwave power> microwave processing time. It can be found that the size of the interaction between the factors from contour map. The shape of contour map is closer to the ellipse, the interaction between the two factors is greater. It can be seen that the order of the interaction of the two factors shown in contour map of Figure 5-7 is as follows, microwave processing time and citric acid mass fraction> microwave power and microwave processing time> microwave power and citric acid mass fraction. Derivation of the regression equation can get the maximum point of the surface. The optimal extraction process parameters are 4.18% citric acid mass fraction , 394Wmicrowave power and 4.4min microwave processing time . The prediction extraction rate of SDF is 47.56% under the optimized condition.



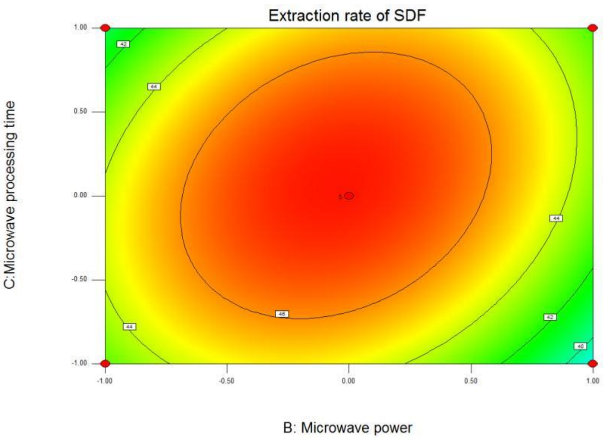
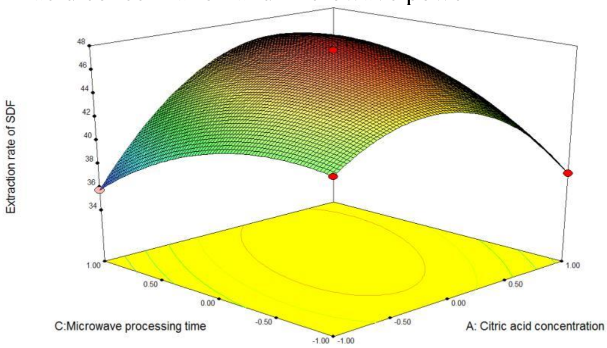


Fig.5 Response surface plot and contour plot of citric acid concentration and microwave power



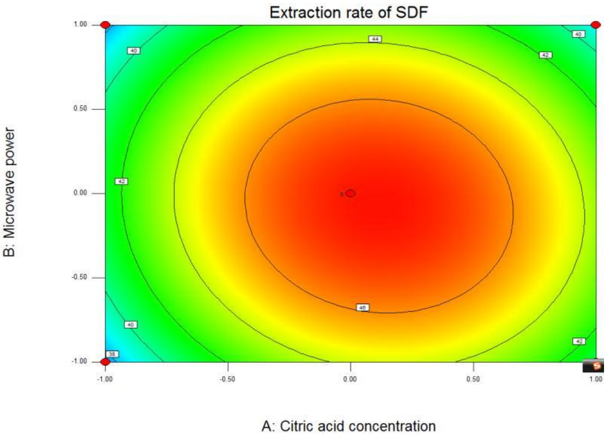
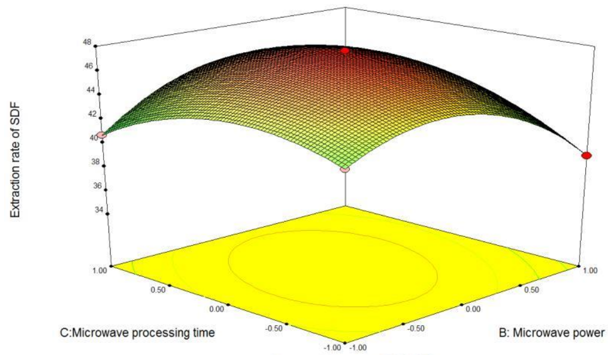


Fig.6 Response surface plot and its contour plot of Citric acid concentration and microwave processing time



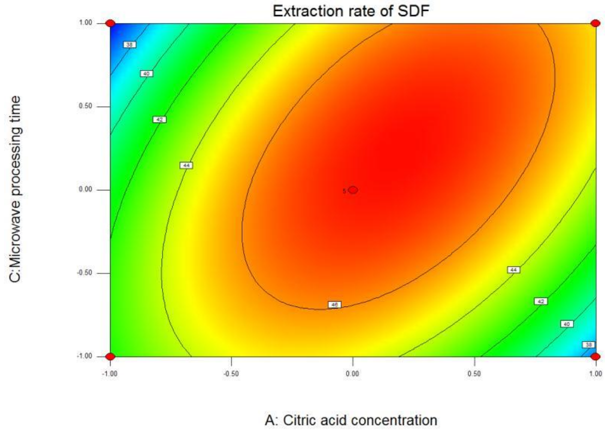


Fig.7 Response surface plot and contour plot of and microwave processing time and microwave power

4 CONCLUSION

In recent years, the ultra-fine pulverization technology is rapidly developed, which pulverizes raw materials to particles with a size of 1nm to 100 μ m, improving the rate of wall breakage, releasing more active ingredients in cells and possessing the characteristics of high liquidity, high fluidity, high adsorption, high chemical reaction activity, etc. And the active ingredients of the material are less damaged.

Studies have shown that the influence of various test factors on SDF yield is different. The yield of SDF increases with the increase of the mass fraction of citric acid,microwave power, extension of time and material-liquid ratio. And the Optimal values are respectively 4%, 400W, 4min and 1:30.

According to response surface diagram and contour diagram, it can be seen that the order of the interaction of the two factors is as follow, microwave processing time and citric acid mass fraction> microwave power and microwave processing time> microwave power and citric acid mass fraction. The optimal extraction process parameters are 4.18% citric acid mass fraction , 394Wmicrowave power and 4.4min microwave processing time . the prediction extraction rate of SDF is 47.56% under the optimized condition.

References

1. S. Yeh, M. Lin, H Chen.Inhibitory effects of a soluble dietary fiber from amorphophallus konjac on cytotoxicity and dna damage induced byfecal water

in Caco-2 cells ［J］.Planta Med,73(13): 1384-1388(2007).

2. Q Wang. Peanut deep processing technology [M]. Beijing: Science Press, 197-198(2014:).
3. L Yu, Q Yang, S Yu, etc. Enzymatic extraction of water-soluble dietary fiber from peanut shells and anti-oxidation research[J]. Food Research and Development, 31(10)158-163(2010).
4. G Zhang, Y Liu , Y Li, etc. Extraction method of soluble dietary fiber from dragon fruit peel[J]. Acta Botany, 52 (5): 622–630(2017).
5. [5] Diao Yan, Chen Bin, Wang Rui, etc. Optimization of the preparation process of pine polyphenol particles by response surface methodology[J]. Food Science, 2019, 40(6):281-288.