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Research Article

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Effects of twin-screw extrusion on soluble dietary fibre of jujube residue

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ABSTRACT

Twin-screw extrusion technology was applied to increase the soluble dietary fibre (SDF) content in jujube residue. Response surface methodology was used to optimize the extrusion parameters. The effect of feed moisture, motor frequency and extrusion temperature on SDF content were evaluated. From the response surface contour plots and from the quadratic regression model equation，the optimal extrusion parameters were as follows: feed moisture 27.5%, motor frequency 34 Hz and extrusion temperature 164 ℃. Under these conditions, the SDF content of jujube residue could reach to 17.67%. Twin-screw extrusion can increase the SDF content of jujube residue.

Keywords: Twin-screw extrusion, Jujube residue, Soluble dietary fibre, Response surface methodology

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INTRODUCTION

Chinese jujube (*Zizyphus jujuba* Miller) for its high nutritional value and good taste has been widely planted in China[1,2]. It has been widely processed as jujube juice. Jujube residue is the main by-product in jujube juice processing, which is a good dietary fibre resource. Total dietary fibre (TDF) can be categorised into two groups, namely soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) [3].But many studies have shown the SDF appears to be more effective than IDF in many healthy aspects[4-6].But the content of soluble dietary fibre (SDF) in jujube residue is lower. So it is important to increase the SDF of jujube residue.

Twin-screw extrusion is a thermal processing that involves the application of high heat, high pressure, and shear forces to foods. It has advantages over other common processing methods because of low cost, speed, high productivity, versatility[7-9]. Many studies has indicated that twin-screw extrusion can increase the SDF in plant residue, such as alfalfa resides[10] and soybean resides[11]. But has little literature for increase the SDF in jujube residue by twin-screw extrusion.

Response surface methodology(RSM), which help to optimum conditions of test, has been successfully applied in many areas such as foods, chemicals or biological processes [12-14].

The aim of this work was to use RSM to optimization extrusion parameters to increase the SDF content of jujube residue.

EXPERIMENTAL SECTION

1.Extrusion experiments

Jujube residue sample (2 kg, SDF content 9.02%, Haoxiangni Co. Henan, China) was extruded with a DS32-IA twin-screw extruder (Jinan Saixin Machinery Co., Jinan, China). The influence factors of feed moisture, motor frequency and extrusion temperature were selected . Feed moisture from 15% to 35%, motor frequency from 29 Hz

to37Hz and extrusion temperature from 150℃ to 190℃.The extruded jujube residue was dried in an oven at temperature of 60℃ and ground to 100 mesh for analysis.

2.Determination of SDF content

The SDF content was determined according to the AOAC method (AOAC, 2005)[15].

3.Test design

According signal factors result, feed moisture (X_1) , motor frequency (X_2) and extrusion temperature (X_3) were used critical various processing parameters. Three levels (low, medium and high) denoted as -1, 0, and +1, respectively. The variables were coded according to equation(1):

$$x_i=(X_i-X_0)/\Delta X_i \quad (1)$$

where x_i is the coded value of an independent variable; X_i is the real value of an independent variable; X_0 is the real value of an independent variable at the center point; and ΔX_i is the step change value. The code and level of factors chosen for the trials in this study are given in Table 1. The response function used was a quadratic polynomial equations as given below:

$$Y = A_0 + \sum_{i=1}^{n} A_i X_i + \sum_{i=1}^{n} A_{ij} X_i X_j \quad (2)$$

As n=3, This equations can give below:

$$Y=A_0+A_1x_1+A_2x_2+A_3x_3+A_{12}x_1x_{2+}A_{13}x_1x_{3+}A_{23}x_2x_{3+}A_{11}x_{12+}A_{22}x_{22+}A_{33}x_{32} \quad (3)$$

Where Y was SDF content; A_0=constant; A_1,A_2 and A_3 were linear coefficients;A_{12}, A_{13} and A_{23} were cross-product coefficients;A_{11}, A_{22} and A_{33} were quadratic coefficients.

Tab.1 Code and level of factors for the trials

Various parameters	Levels		
	-1	0	1
feed moisture /%	20	25	30
motor frequency /Hz	31	33	35
temperature e /℃	150	160	170

RESULTS AND DISCUSSION

1.Determining levels for independent variable

The effect of different feed moisture on SDF content was examined at 15% to 35%, when the other extrusion conditions were set as follows: motor frequency 33Hz, extrusion temperature 160℃(Fig.1A). It showed that SDF content increased when feed moisture from 10% to 20%.The maximum SDF content was the feed moisture 25%, after this point, the content of SDF started to decrease with the increasing of the feed moisture.

The influence of motor frequency on the content of SDF was investigated at 29Hz to 37Hz, when the other extrusion conditions were set as follows: feed moisture 25%, extrusion temperature 160℃ (Fig.1B) .It showed that SDF content increased when motor frequency from 29Hz to 33Hz. The maximum SDF content was the motor frequency 33Hz, after this point, the content of SDF increase slower with the increasing of the motor frequency.

The influence of temperature on the content of SDF was investigated at 150℃ to 190 ℃ ,when the other extrusion conditions were set as follows: feed moisture 25%, motor frequency 33Hz (Fig.1C) .It showed that SDF content increased when temperature from 150℃ to 160 ℃. The maximum SDF content was the temperature 160 ℃, after this point, the content of SDF decrease r with the increasing of the temperature.

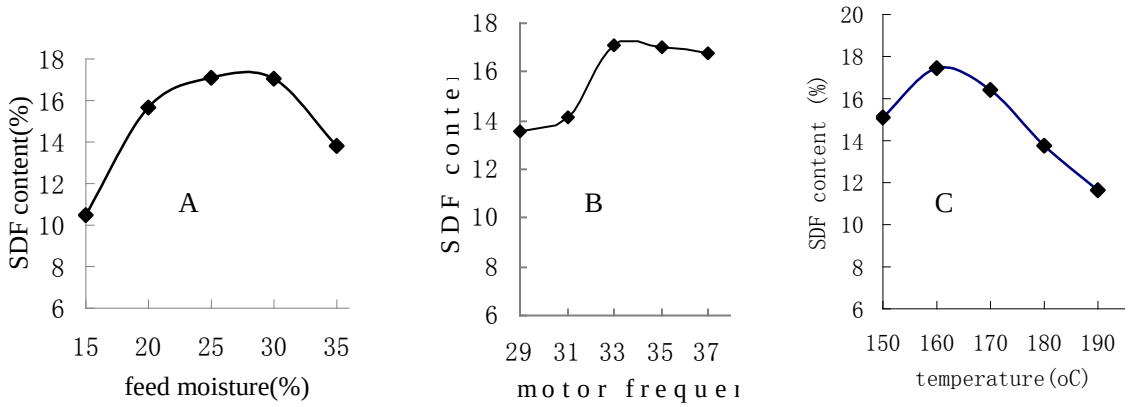

Fig.1 Effect of independent variable on SDF contents

2.Regression model and statistical analysis

According the design, the test results were presented in Table2.

Tab.2 Experimental design and results

No.	X_1	X_2	X_3	Y（%）
1	1	0	-1	15.29
2	-1	0	1	13.13
3	0	0	0	17.67
4	-1	1	0	14.03
5	0	1	1	17.27
6	1	0	1	16.23
7	0	0	0	17.48
8	0	1	-1	13.98
9	0	0	0	17.42
10	0	-1	-1	12.25
11	1	1	0	17.38
12	-1	0	-1	12.62
13	1	-1	0	12.66
14	0	0	0	17.51
15	0	0	0	17.44
16	-1	-1	0	10.25
17	0	-1	1	11.19

Results were analyzed by RSM, and the regression model of the effect of different variables including interaction between variables on the Y was also obtained. Regression equation as follows equation (4):

$$Y=16.89+0.69x_1-+0.63x_2+0.23x_3+0.25x_1x_2+0.07x_1x_3+0.28x_2x_3-0.68x_1^2-0.69x_2^2-0.59x_3^2 \quad (4)$$

Statistical analysis of quadratic regression model was tested by the Fisher's F-test for analysis of variance (ANOVA). The statistical software package Design-Expert 6.0 from Stat-Ease was utilized on a PC running under windows. The analysis of variance for regression equation were shown in Table3.

Tab.3. Analysis of variance for regression equation

	sum of squares	D_f	mean square	F	Prob>F	significance
Model	104.80	9	11.64	466.07	<0.0001	*
x_1	16.62	1	16.62	665.10	<0.0001	*
x_2	33.25	1	33.25	1330.88	<0.0001	*
x_3	1.69	1	1.69	67.75	<0.0001	*
x_1x_2	0.22	1	0.22	8.84	0.0207	*
x_1x_3	0.046	1	0.046	1.85	0.2159	
x_2x_3	4.73	1	4.73	189.34	<0.0001	*
x_1^2	11.32	1	11.32	452.98	<0.0001	*
x_2^2	21.97	1	21.97	879.51	<0.0001	*
x_3^2	10.08	1	10.08	403.31	<0.0001	*
residual	0.17	7	0.025			
lack of fit	0.14	3	0.045	4.60	0.0873	
net errors	0.039	4	9.830E-003			
total Error	104.98	16				
R^2	0.9983	Correction R^2	0.9962			

This result shown the value of the determination coefficient (R^2=0.9983) is higher. The significance of each coefficient was determined by *F*-value and *p*-value which are listed in Table3. the *p*-value of x_1,x_2,x_3,x_1x_2,x_2x_3,x_1^2,x_2^2 and x_3^2 is less than 0.0001, this implies that they have very significance effect.

3.Optimization of extrusion parameters

The effect of one factor solely depends on the value of the other. Figure1A represents that interaction between the feed moisture and motor frequency on SDF content and Figure1B represents that interaction between the temperature and motor frequency on SDF content.

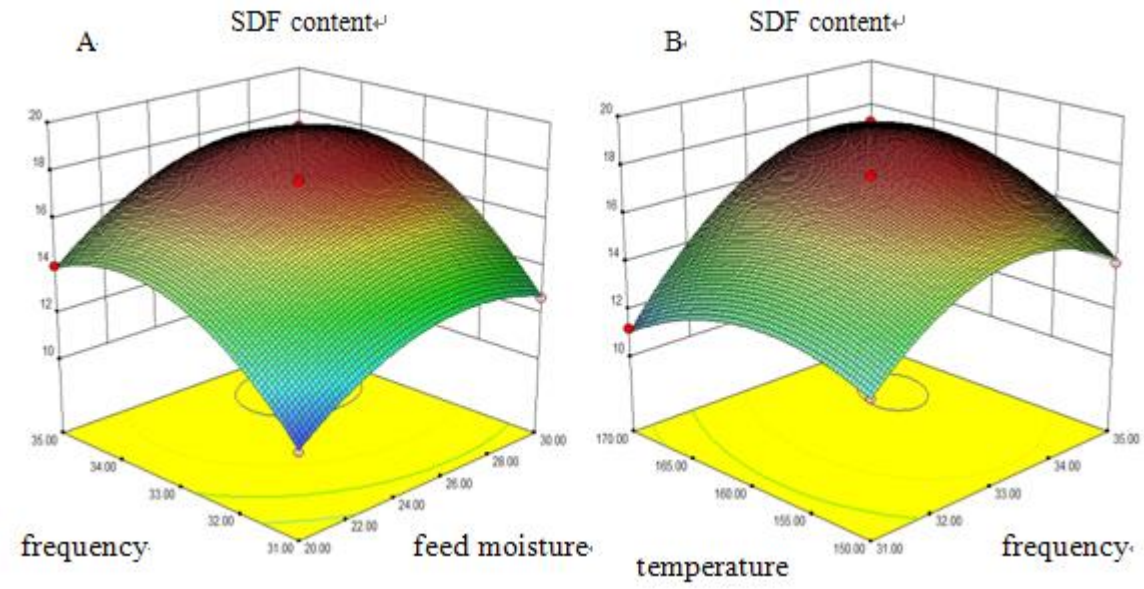

Fig.1 Response surface plot and it's contour plot of the effect of feed moisture, motor frequency , temperaturer and their mutual interactions on SDF content

From the response surface contour plots, the optimal values of the test variables: feed moisture,motor frequency and temperaturer were selected as 27.5%, 34 Hz and 164℃. The values were substituted in the regression equation which was solved by Gauss-Jordon method. The maximum SDF contente predicted by the equation (17.76%) agrees well with the experimental value (17.67%) obtained from the experimental verification at the optimal values.

CONCLUSION

In this paper, the SDF content (17.67%) prepared from jujube residue by twin-screw extrusion was significantly higher than the unextrusion SDF content (9.02%) prepared from jujube residue. It indicated that the twin-screw extrusion technology can significantly increase the SDF content in jujube residue. The optimal condition of the were: soaking time120min , ultrasound wave feed moisture 27.5%, motor frequency 34 Hz and extrusion temperature 164℃.

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