Research on the parameters of producing filamentous textured soybean protein with soybean protein isolated and soybean protein concentrate

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Abstract. Textured soybean protein (TSP) is a product made from cooking and extrusion of soybean protein, which has been widely used in food, feed and other industries. This text made soybean protein isolated (SPI) and soybean protein concentrate (SPC) as the raw materials to produce filamentous protein production. By experiment, the influence of puffing temperature, screw speed and feed rate on the quality of the protein products was studied. Finally it was concluded that when the temperature of the barrel was 152 ℃, the screw rotation speed was 119 rpm, the feed rate was 0.426 kg/min, the TSP product had the biggest expansion degree.

1 INTRODUCTION

Protein is one of the important nutrients in food and plays an important role in improving human immunity. Soybean is rich in soybean protein, and more efficient proteins are developed from soybean, which is beneficial to the improvement of human life quality.

Soybean is rich in protein, and has been an important cash crop which has been widely cultivated all around the world. As the raw material for soybean oil, soy-based products, such as soymilk and tofu, soybean is widely consumed in China[1]. At present, the processing degree of soybean is low, which is based on primary processing. How to further process the soybean and improve the added value of soybean products is one of the key problems to be solved in soybean production.

As a high-grade product, textured soybean protein (TSP) is more and more popular in the market because of its high protein content, low cost, simple production process and tastes like meat. At present, TSP products in the market have the bean smell and the structure are in a bad state. One main reason is partly because the raw materials are improperly selected, and the other reason is that the processing technology is improperly selected[2-4].

So far, there have been few studies on textured soybean protein production. In fact, many parameters such as the temperature, feed rate, screw rotation speed would affect the quality of TSP products[5-7].

In this study, soybean protein isolated (SPI) and soybean protein concentrate (SPC) were used as raw materials, flour and corn flour were used as auxiliary materials to produce TSP by improving processing technology and controlling processing parameters. The protein content of the product was high, the expansion degree was good, and the taste of the product was better. We hope our research might provide more reference for actual production.

2 MATERIALS AND METHODS

2.1 Materials

Soybean protein isolated powder (Harbin Gongda Protein Factory), soybean protein concentrate powder (Qinhuangdao Jinhai Cereals and Oils Co., Ltd.), other raw materials are commercially available.

2.2 Instruments

Soxhlet extractor (Tianjin Tianke Glass Instrument Manufacturing Co., Ltd.), micro-Kjeldahl nitrogen plant (Tianjin Tianke Glass Instrument Manufacturing Co., Ltd.), DS56-III twin-screw extruder (Ji Nan Saixin Extrusion Machinery Co., Ltd. the company).

2.3 Experimental

2.3.1 Determination of main raw material composition

The raw material included SPI, SPC, flour, corn flour. Because the usage amount of flour and corn flour was very few, their nutrients were refer to market averages. The test items included protein, fat, water, ash and nitrogen solubility index.

2.3.2 The production process

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The raw and auxiliary materials were weighed in a certain proportion, and mixed well. The twin-screw extruder needed to warm up half an hour in advance. After the machine parameters were set, the feed production test was carried out. Pay attention to the changes of materials and processing parameters in the production process at any time, and turned off the machine switch after the experiment. The expansion degree of the product was tested to analyze the quality difference of the product under different experimental conditions.

3 RESULTS AND DISSCUSSION

3.1 Raw material composition determination results

Table 1. Results of determination of main raw material components in extrusion test.

Raw material	Protein/ %	Fat/%	Water/ %	Ash/%	Nitrogen solubility index/%
SPC	71.3	0.85	5.3	5.5	71.6
SPI	91.5	0.65	3.4	3.7	89.7

It could be seen from Table 1 that the protein contents of both main raw materials were greater than 50%, and the nitrogen solubility index was greater than 70%, which was consistent with the requirements of the production of tissue proteins for the raw materials used. In this research, the ratio of raw materials was: SPC (40%), SPI (40%), flour (10%), and corn flour (10%). Such ratio not only ensured normal production, but also met the requirements of high protein and low cost[8].

3.2 Effect of single factor effect on the expansion degree (Y)

In order to better study the effect of production conditions on TSP, the mathematical model was used to optimize the condition. Three main factors, such as the temperature, screw speed, and feed rate were chosen (Table 2).

Table 2. Experimental factors and their range of variation.

No	Factors	Range of variation
Z1	Temperature (°C)	130~160
Z2	Screw speed (rpm)	60~120
Z3	Feed rate (kg/min)	0.2~0.6

3.2.1 Effect of temperature (X_1) on the expansion degree (Y)

In order to intuitively find out the influence of the barrel temperature (X_1) on the index, set $X_2=X_3=-1$; $X_2=X_3=0$; $X_2=X_3=1$, and the following three equations could be obtained:

$$Y_1=3.20+0.39X_1-0.23X_1^2 \quad (1)$$

$$Y_2=3.58+0.39X_1-0.23X_1^2 \quad (2)$$

$$Y_3=3.36+0.39X_1-0.23X_1^2 \quad (3)$$

The curves of the equations were shown in Figure 1:

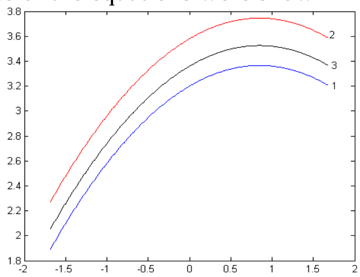

Figure 1. Effect of temperature on the expansion degree.

As shown in Figure 1, the curve of the processing temperature on the expansion degree was parabolic. When the processing temperature was increased, the expansion degree of the product increased, but under a certain extent, the expansion degree decreased. The reasion was that within a certain temperature range, increasing the temperature made the material more favorable for gelatinization and increased the expansion degree of the product.

3.2.2 Effect of screw speed (X_2) on the expansion degree (Y)

X_1 and X_3 were fixed and the following equation could be obtained:

$$Y_1=2.56-0.02X_2^2 \quad (4)$$

$$Y_2=3.58+0.27X_2^2 \quad (5)$$

$$Y_3=2.96+0.56X_2^2 \quad (6)$$

The curves of the equations were shown in Figure 2:

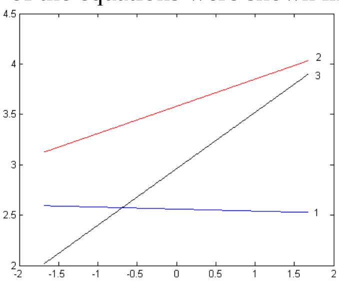

Figure 2. Effect of screw speed on the expansion degree.

As shown in Figure 2, curve 1 was relatively flat, indicating that when the barrel temperature and the feed rate were very slow, it was difficult to expand the material, and the material had to be expanded to have a certain temperature to change the internal structure. For curve 2 and curve 3, it could be seen that at a certain temperature and feed rate, as the screw speed increased, the internal action of the material increased, and the expansion degree increased. For the actual production, the screw speed could be increased within a certain range to increase the product expansion degree and output, but the screw speed could not be too fast, otherwise it was easy to block the material and the product was not expanded[8-13].

3.2.3 Effect of feed rate (X_3) on the expansion degree (Y)

Fixing X_1 and X_2, the following equations could be obtained:

$$Y_1=2.69-0.48X_3-0.59X_3^2 \quad (7)$$
$$Y_2=3.58-0.19X_3-0.59X_3^2 \quad (8)$$
$$Y_3=4.01+0.10X_3-0.59X_3^2 \quad (9)$$

The curves they presented were shown in Figure 3.

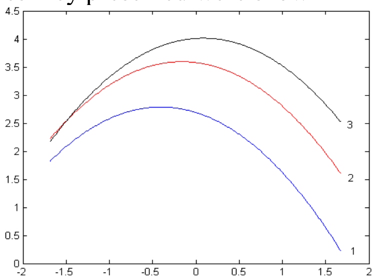

Figure 3. Effect of feed rate on the expansion degree.

As shown in Figure 3, within a certain range, as the temperature of the barrel rised, the internal gelatinization of the product was enhanced, and the expansion degree of the product was increased, but when the temperature exceeded a certain temperature, the product would be burnt, the structure became hard, the surface was browned, and the expansion degree was lower. For actual production, the product could be expanded within a certain temperature range, and the temperature was slightly higher, which was more conducive to product expansion.

3.3 Two-factor effect analysis

3.3.1 Effect of screw speed (X_2) and feed rate (X_3) on the expansion degree

By fixing the barrel temperature (X_1) at the 0 level, a model of the screw speed (X_2) and the feed rate (X_3) versus the expansion degree could be obtained:

$$Y=3.58+0.27X_2-0.19X_3+0.29X_2X_3-0.59X_3^2 \quad (10)$$

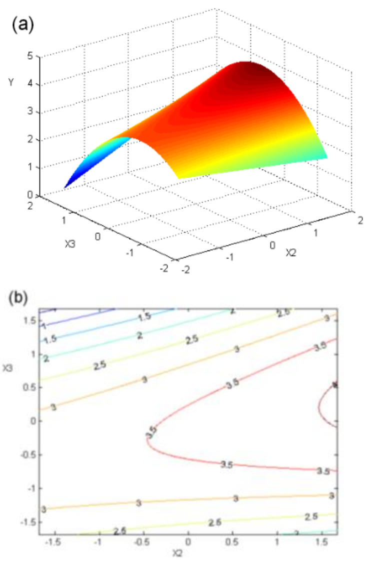

Figure 4. Effect of screw speed and feed rate on the expansion degree.

It could be seen from the Figure 4 that the screw speed X_2 = 1.48 ~ 1.68, and the feed rate X_3 = -0.2 ~ 0.45 had the largest expansion degree. This range could be used as the scope of the subsequent verification experiment. The mechanism was that when the screw speed and feed rate were larger, the processing ability began to be stronger. The extreme points were selected as: X_1 = 0, X_2 = 1.68, X_3=0.45, and the subsequent experiments were verified.

3.3.2 Effect of barrel temperature (X_1) and feed rate (X_3) on the expansion degree

By fixing the screw speed (X_2) at the 0 level, a model of the barrel temperature (X_1) and the feed rate (X_3) versus the expansion degree could be obtained:

$$Y=3.58+0.39X_1-0.19X_3-0.23X_1^2-0.59X_3^2 \quad (11)$$

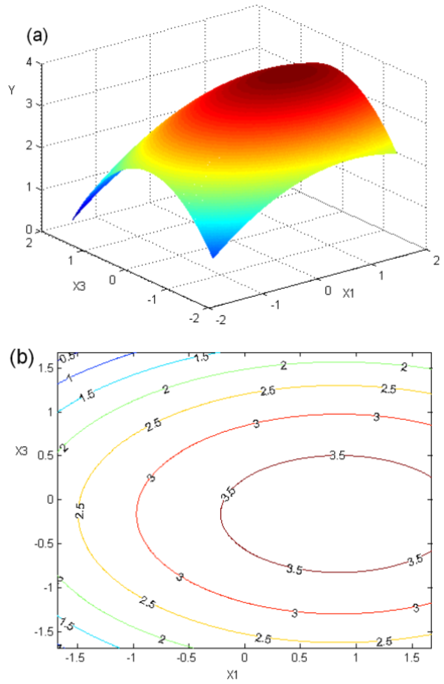

Figure 5. Effect of barrel temperature and feed rate on the expansion degree.

When the barrel temperature X_1 = -0.3 ~ 1.68, the product had the highest expansion degree; when the feed rate X_3 = -0.75 ~ 0.45, the product had the highest expansion degree, which could be used as the scope of subsequent verification experiments. The mechanism was that when the temperature of the barrel was higher, the interaction among the raw materials was enhanced, the product was more conducive to puffing. The extreme point was selected as: X_1 = 1.68, X_2 = 0, X_3 = 0.45.

3.3.3 Influence of barrel temperature (X_1) and screw speed (X_2) on the expansion degree

$$Y=3.58+0.39X_1+0.27X_2-0.23X_1^2 \quad (12)$$

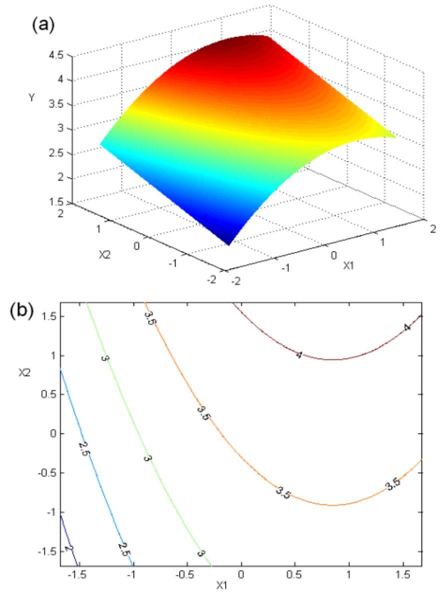

Figure 6. Effect of temperature and screw speed on the expansion degree.

When the barrel temperature X_1= -0.1 ~ 1.68, the product had the highest expansion degree; when the screw speed X_2 = 0.95 ~ 1.68, the product had the highest expansion degree, which could be used as the scope of subsequent verification experiments. The mechanism was that when the temperature of the barrel was higher, the interaction among the raw materials was enhanced, which was more conducive to puffing; when the screw was higher, the product feed began to be smoother. The extreme point was selected as: X_1 = 1.68, X_2 = 1.68, X_3 = 0.

3.4 Optimization of process parameters

Regression equation for the expansion degree: $Y=3.58+0.39X_1+0.27X_2-0.19X_3+0.29X_2X_3-0.23X_1^2-0.59X_3^2$

The optimized condition was that: when X_1=0.85, X_2=-3.13, X_3=-0.93, the Y value was equal to 2.57. Because the range of X was between -1.682 and 1.682, X was out of range, therefore, it had no meaning for this equation and should be discarded.

The three extreme points were obtained by the two factors and the extreme points were obtained by the optimization program. Some random datas were also selected as the experimental parameters, The extrusion experiment optimized parameters were shown in Table 3.

Table 3. Extrusion experiment optimized parameters.

No	X_1	X_2	X_3	Y(By equation)	Y(By experiment)	Error	Fractional error(%)
1	0	1.68	0.45	4.04	3.85	-0.19	4.70
2	1.68	0	0.45	3.70	3.92	0.20	5.41
3	1.68	1.68	0	4.04	4.19	0.15	3.71
4	0.82	1.62	0.22	4.15	4.29	0.14	3.37
5	0	0	0	3.58	3.73	0.15	4.19
6	-0.5	0	0.5	2.94	3.21	0.27	9.18

As shown in Table 3, No 4 had the highest Y value, no matter by equation and by experiment. The X_1, X_2, X_3 were all in the range of -1.68 and 1.68, it was seen that the values obtained were shown to be valid. The error and fractional error were relatively low, indicating a good reproducibility of the experiment, we could use equations to simulate actual production. Changed the code of the equation into the actual operating parameters, and we got the optimal condition was that: when the temperature of the main barrel was 152 ℃; the screw speed was 119 rpm; the feed rate was 0.426 kg/min, the expansion degree was highest.

Conclusions

In our experiment, the optimal condition for the production of filamentous TSP was obtained by equation modeling and experimental operation. It was proved that the equation modeling was a better method to optimize the optimal condition. The error between the equation modeling and experimental operation was lower (<10%), it illustrated the feasibility of the method. We hope our research might provide more reference for actual production.

Acknowledge

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