The effects of extrusion on tannin content in rapeseed meal

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Abstract

In the paper, tannin content was employed as evaluation index; heating temperature of extruder sleeve, moisture of extruder feed material and rotation speed of extruder screw were considered. Three factors and three levels were implemented into the combined test design of quadratic orthogonal rotation, a regression equation and single factor graphical analysis were used to demonstrate the rule of influential factors on test indices, and investigate the contribution rate of test factors to index factors. The above built a theoretical basis for the comprehensive utilization of extrusion technology in the processing by-products of rape.

Keywords: tannin, test design, extrusion

Introduction

Rapeseed meal contains 28%~ 45% proteins, its biological value PER of amino acid is superior to that of soybean protein and is close to the value recommended by WHO/FAO, and it is a full protein. Therefore, research on the protein extracted from rapeseed meal (Xu, L., and Dio-sady., 1994), the confirmation of proteolytic conditions (Pang Guangchang, 1999) as well as acylated polypeptide & compound amino acid made from rapeseed protein (Jacques G., 1990; Wang Zhijun, 2001), etc. has been carried out in foreign countries with obvious progress. The anti-nutritional factors such as glucosinolate, tannin and phytic acid in rapeseed meal limit the extraction and utilization of this excellent protein source. The adverse effects of toxic glucosinolate on rapeseed protein have been well removed by breeding, however, the content of anti-nutritional factors of tannin and breeding now cannot reduce phytic acid, etc. So, a substrate processing method by which the protein recovery rate can be enhanced and the content of anti-nutritional factors of tannin and phytic acid, etc. can be reduced at the same time is to be found. Extrusion puffing is a high technology. Used in the extrusion of rapeseed meal, it can deactivate the anti-nutritional factors of tannin and phytic acid, etc., release the protein combined with tannin and phytic acid, and cause protein denaturation. All of these help the hydrolase action and enhance the protein recovery rate. In this paper the variation rule of tannin content in rapeseed meal under different extrusion conditions was mainly discussed. The extrusion processing of substrate to enhance proteolytic efficiency and deactivate phytic acid will be reported in another paper.

Material and Methods

Materials and Reagents

Rapeseed meal (provided by Hubei Huayi Oil Technology Co., Ltd.; moisture 10.34%, protein 42.48%, tannin 1.21% and phytic acid 3.66%), isatin, $KMnO_4$, bone black powder and concentrated H_2SO_4 etc. All the reagents belong to AR level.

Apparatus

DS32-II Single Screw Extruder (Shandong Saixin Inflating Machinery Co., Ltd.), DE110 Electronic Analytical Balance (Changshu Weighing Apparatus Factory of China Light Industry Machinery General Corporation), HH·SY11-Ni 4B Thermostat Water Bath (Beijing Changfeng Instrument and Meter Co., Ltd.), HG101-1 Electric Blast Drying Oven (Nanjing Laboratory Apparatus Factory), DWF-100 Electric Plant Crusher (Scientific Research Instrument Factory of Huangye City, Hebei Province), LNK-872 Versatile Fast Digester (Research Institute of Scientific and Educational Instrument, Yixing City, Jiangsu Province), LNK-871 Kjeldahl Nitrogen Determination Apparatus (Research Institute of Scientific and Educational Instrument, Yixing City, Jiangsu Province), 78-1 Magnetic Stirrer (Jiangsu Jintan Medical Instrument Factory), etc.

Methods

Determination of Tannin Content in Rapeseed Meal

Potassium permanganate titration is used. Tannin can be absorbed active bone coal and oxidized by potassium permanganate. Tannin content can be calculated according to the difference between oxidizing values before and after absorption reaction. Isatin is oxidized by potassium permanganate, turning from blue to yellow so as to indicate the end.

Respectively suck up 0, 1, 3, 5, 10 and 15mL from 400μg/mL tannin standard solution (equivalent to 0, 400, 1200, 2000,

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4000 and 6000μg of tannin content), determine them by the newly prepared $KMnO_4$ solution, and draw the following standard curve as Figure 1.

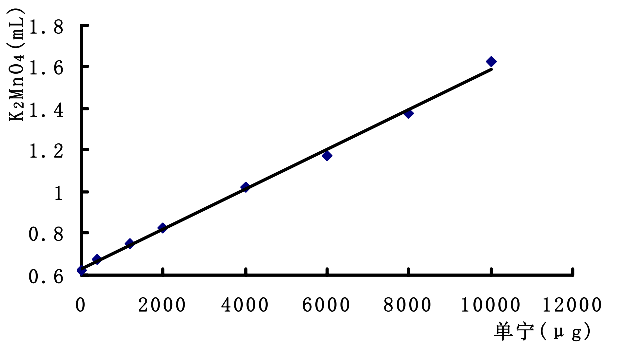

Figure 1. The Standard Curve of Tannin Determination

Design

Table 1. Code Table of Factors and Levels

Level	X_1 Temperature (°C)	X_2 Screw Speed ($r.min^{-1}$)	X_3 Moisture (%)
-1.682	33	166	17
-1	40	180	20
0	50	200	25
1	60	220	30
1.682	67	234	33

The regression equation between K_2MnO_4 and tannin content is obtained by the standard curve:

$$Y=1 \times 10^{-4}X+0.6288; R2=0.9968$$

Calculate the tannin content of rapeseed meal under different extrusion conditions by the regression equation.

Table 2. Implementation Plan and Test Date

No.	X_1	X_2	X_3	Y tannin (%)
1	1	1	1	0.9056
2	1	1	-1	0.7360
3	1	-1	1	0.8671
4	1	-1	-1	0.7895
5	-1	1	1	0.8616
6	-1	1	-1	0.7915
7	-1	-1	1	0.8934
8	-1	-1	-1	0.8737
9	1.682	0	0	0.7783
10	-1.682	0	0	0.8031
11	0	1.682	0	0.6313
12	0	-1.682	0	0.5719
13	0	0	1.682	0.8744
14	0	0	-1.682	0.8896
15	0	0	0	0.8071
16	0	0	0	0.7391
17	0	0	0	0.6847
18	0	0	0	0.7973
19	0	0	0	0.8066
20	0	0	0	0.7035
21	0	0	0	0.7973
22	0	0	0	0.8066
23	0	0	0	0.8723

Note: X_1-temperature of extruded material, X_2-rotation speed of extruder screw, X_3-moisture of feed material

Based on the relevant documents and reports (Zhu Zeng, 1995; Shen Dechao, 1999) and combined with the actual conditions of existing extruders, select three factors, i.e. temperature of extruder sleeve, moisture of feed material and rotation speed of extruder screw, as extrusion parameters, at the same time, select five levels, and use the quadratic orthogonal rotation combination to design and arrange the test (Xu Zhongru, 1988). See Table 1 for Factor Level coding Table. Perform data analysis and graphic processing and research on the rule of effect of each parameter on tannin content in investigation index-rapeseed dregs with computer software.

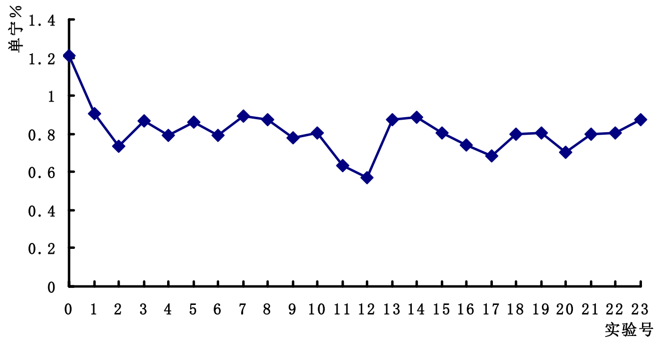

Figure 2. Changes of Tannin Content under Different Test Conditions

Results and Discussion

Changes of Tannin Content under Different Test Conditions

Figure 2 indicates the tannin content in rapeseed meal as raw material and the tannin content corresponding to each test number in Table 2.

The Regression Equation with Tannin Content as Evaluation Index

The test data are processed by computer to get the regression equation with tannin content as evaluation index:

$$Y=0.778-0.012X_1-0.002X_2+0.023X_3+0.021X_1^2+0.012X_1X_2+0.020X_1X_3-0.046X_2^2+0.018X_2X_3+0.053X_3^2$$

The following is the variance analysis table of regression equation

Table 3. Variance Analysis Table

Source	Sum of Squares	Degree of Freedom	Mean Square	F Value	Critical Value
Regression	D_r=0.102	f_r=9	0.0113	F_2=4.9982	$F_{0.1}(9,13)$=2.16
Surplus	D_s=0.061	f_s=13	0.0047		
Fitting	D_f=0.033	f_f=5	0.0066	F_1=3.6159	$F_{0.05}(5,8)$=3.69
Error	D_e=0.028	f_e=8	0.0035		
Total	D_t=0.163	f_t=22			

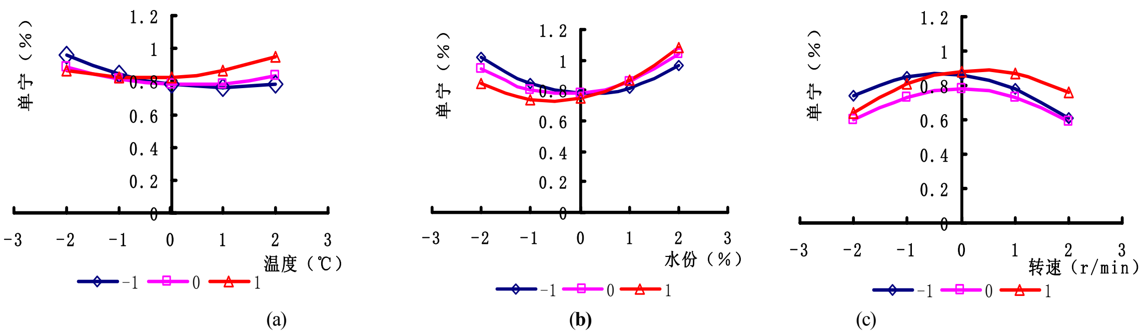

Figure 3. Single Factor Analysis of Tannin Content

The Factor Contribution Rate of the effects of Extruder Parameters on the Tannin Content in Rapeseed Meal.

The model shows that the contribution rates of the effects of factors on tannin content are respectively: material moisture $X_3$1.888> rotation speed of extruder screw $X_2$1.310 > temperature of extruder sleeve $X_1$1.379.

Discussion

The Extrusion Effects on Tannin Content in Rapeseed Meal

Table 2 and Figure 2 indicate that the tannin content in rapeseed meal varies with the extrusion conditions, the tannin content in 23 groups of material under different extrusion conditions is all lower than that in the raw material, and the tannin content of No.12 sample is even reduced to nearly 50% of that in the raw material. So extrusion obviously deactivates tannin.

Variance Analysis of Regression Equation

In Table 1, $F_1<F_{0.05}$ (5,8) =3.69, which shows that the regression equation is well fit; $F_2>F_{0.1}$ (9,13) =2.16, which shows that the equation is obvious in 0.1 level, i.e. the test data substantially matches the mathematical model.

Single Factor Analysis of the Effects of Test Factors on Indices.

Figure 3 is the dimension reduction analytic map for the affects of extrusion parameters on the investigated indices under -1,0,+1 level conditions.

Figure 3 (a) is the curve in which the tannin content in rapeseed meal varies with X_1 when X_2 and X_3 are respectively fixed at -1, 0, +1 level. The dimension reduction analysis equations corresponding to different level values are respectively $f(x_1) = 0.0212x_1^2-0.0440x_1+0.7826$, $f(x_1) = 0.0212x_1^2-0.0120x_1+0.7776$, $f(x_1) = 0.0212x_1^2+0.0201x_1+0.8239$. Figure (a) indicates that the tannin content changes with the temperature of extruder sleeve substantially in the same way in case of other factors fixed at different levels. As the temperature of extruder sleeve rises, the tannin content first falls and then rises, without great fluctuation. The graphical analysis indicates that the temperature of extruder sleeve has little impact on the tannin content, and is a minor parameter influencing the changes of tannin content.

Figure 3 (b) is the curve in which the tannin content in rapeseed meal varies with X_2 when X_1 and X_3 are respectively fixed at -1, 0, +1 level. The dimension reduction analysis equations corresponding to different level values are respectively $f(x_2) = -0.0456x_2^2-0.0323x_2+0.8612$, $f(x_2) = -0.0456x_2^2-0.0021x_2+0.7776$, $f(x_2) = -0.0456x_2^2+0.0280x_2+0.8828$. Figure (b) indicates that the tannin content changes with the rotation speed of extruder screw substantially in the same way in case of other factors fixed at different levels. As the rotation speed of extruder screw rises, the tannin content first rises and then falls, with obvious changing trend. It is because: as the rotation speed rises, the residence time of material in the chamber is shortened, tannin is less deactivated, and its content rises; as the rotation speed go on rising, the shearing action of screw on material is strengthened, the strengthened degree of tannin due to deactivation is higher than the weakened degree due to the reduced residence time of material, so the tannin content falls.

Figure 3 (c) is the curve in which the tannin content in rapeseed meal varies with X_3 when X_1 and X_2 are respectively fixed at -1, 0, +1 level. The dimension reduction analysis equations corresponding to different level values are respectively $f(x_3) = 0.0535x_3^2-0.0147x_3+0.7797$, $f(x_3) = 0.0535x_3^2+0.0228x_3+0.7776$, $f(x_3) = 0.0535x_3^2+0.0603x_3+0.7514$. Figure (c) indicates that the tannin content changes with the moisture of extruded material in the same way in case of other factors fixed at different levels. As the moisture of material rises, the tannin content first falls and then rises. It is because: proper moisture is helpful to the instantaneous puffing of material being extruded from the die orifice, and tannin is more deactivated; as the material moisture go on rising, the fluidity of extruded material gets better, the residence time in extruder chamber is shortened, and tannin is less deactivated.

Analysis of Factor Contribution Rate

The values of contribution rates indicate: The two factors of the moisture of extruded material and the rotation speed of extruder screw have greater influence on the changes of tannin content in rapeseed meal; the temperature of extruder sleeve has less influence on the changes of tannin content, which can be regarded as a minor factor in production. The analysis of factor contribution rate basically corresponds with the conclusion of graphical analysis.

Conclusions

The results indicate that extrusion obviously deactivates tannin, a resistance factor in rapeseed meal affecting protein absorption. The tannin content of rapeseed meal varies with the extruder parameters: as the temperature of extruder sleeve rises, the tannin content first falls and then rises, without great fluctuation; as the rotation speed of extruder screw rises, the tannin content first rises and then falls; as the moisture of material rises, the tannin content first falls and then rises. Among the three factors selected in the test, the moisture of material is the major factor affecting the changes of tannin content, the rotation speed of extruder screw has the second influence, and the temperature of extruder sleeve in the selected range of 33~67°C has the least influence. The curve trend in dimension reduction analytic map basically corresponds with the conclusion of theoretical analysis.

Acknowledgements

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