Design Engineering

ISSN: 0011-9342

Issue: 11 | Pages: 163 - 181

Test and Analysis on the Molding Process Parameters of Alkalized Peanut Straw

Fang Ma, Congqing Shao*, Zhongyu Chen*

Automotive Engineering School, Yancheng Polytechnic College, Yancheng, Jiangsu, China

*Corresponding Author: Congqing Shao, Zhongyu Chen

Abstract:

Peanut is an important oil crop and economic crop, whose straw is often used as livestock feed owing to its aromatic smell and rich nutrition. However, air-dried peanut straws have high hardness, poor palatability, low digestibility, plus loose structure and high storage and transportation costs, which affect its feed utilization. To solve the above problems, peanut straws are first alkalized to reduce the hemicellulose and lignin contents, thereby increasing its palatability and digestibility. Next, the alkalized peanut straws are subjected to single-hole compression molding experiments. Finally, the combination of appropriate process parameters is determined as follows: the average straw crushing particle size is about 5mm, the moisture content is between 10%~11%, the flat die hole diameter is 8mm, and the die hole length is 27mm. The compression molding test using a flat die pellet feed machine shows that the peanut straw pellet feed produced under this set of process parameters has a smooth surface, with molding rate up to 98.33%.

***Keywords**: Peanut, Straw, Molding.*

I. INTRODUCTION

Peanut is an important oil crop and economic crop in the world. According to statistics from the United States Department of Agriculture, as of 2019, more than 100 countries around the world have planted peanuts. In China, the planting area, per unit yield and total output of peanuts in the past 10 years have been on the rise year by year. With the increasing peanut output year by year, peanut straws have steadily increased output year by year, which are often used as livestock feed due to its aromatic smell and rich nutrition. The crude protein content of air-dried peanut straws can exceed 15%, which is 5 times that of Leymus chinensis. Its crude fat content is close to 5%, which is more than 5 times that of soybean straw and 20 times that of barley straw [1-3]. At present, there are two key problems hindering feed conversion of peanut straws: one is the high hardness of air-dried peanut straws and increased degree of lignification, which not only affects the palatability, but also reduces the digestibility of nutrients; the second is the loose structure of peanut straws, the high transportation and storage cost.

To promote feed utilization of peanut straws, firstly, peanut straws must be pretreated to enhance its palatability, improve the digestibility and nutrient content, and extends the shelf life; secondly, the pretreated straws should be compressed to increase the density and reduce the volume on the premise of meeting feed quality standard, so that its storage and transportation cost is lowered. The purpose of this study is to correlate the two issues, find the optimal solution, and determine the relevant parameters.

II. MATERIALS AND METHODOLOGY

Alkalization is a common pretreatment method in feed conversion of straw. Pretreatment with this method facilitates compression molding of straw, and straw particles after molding have more stable shape and size [4]. The principle of alkalized straw is to use alkaline drugs to weaken the hydrogen bonds in the straw, destroy the ester and ether bonds, expand the cellulose molecules, dissolve hemicellulose and part of the lignin, so that the gastric juice and digestive enzyme in the digestive tract of livestock can more easily penetrate into the feed tissues, which can improve the palatability while increasing feed intake and digestibility. Commonly used chemicals include sodium hydroxide and lime. In this study, the peanut straw will be pretreated with alkalization and then crushed, followed by single-hole compression molding test to determine the optimal process parameters.

2.1Materials

In this experiment, 30 peanut straws from Huayu in Liaoning were selected, cut into sections (with a length of about 4cm), and then mixed with 8% NaOH solution at a ratio of 1:10. After sealing for 7 days, add alkali for 72h reaction [5, 6]. The peanut straw after alkalization has soft texture and fragrant aroma.

Design Engineering

ISSN: 0011-9342

Issue: 11 | Pages: 163 - 181

The lignocellulose content of untreated peanut straws and alkalized peanut straws is determined by Van Soest detergent fiber analysis method. First, the sample is boiled with neutral detergent, and the insoluble filter residue is neutral detergent fiber NDF, which is mainly composed of cellulose, hemicellulose, acid-insoluble lignin and silicate. After the sample is treated with acid detergent, the undissolved filter residue is the acid detergent fiber ADF, which is mainly composed of cellulose, acid-insoluble lignin and silicate. From the above two chemical components, it can be seen that the difference between the contents of neutral detergent fiber and acid detergent fiber is the hemicellulose content. The acid detergent fiber obtained from the above method is treated with 72% concentrated sulfuric acid, and the resulting filter residue is the strong acid detergent lignin ADL, which is mainly composed of lignin and silicate. The sample cellulose content is obtained by subtracting the strong acid detergent lignin from the acid detergent fiber value. After the strong acid detergent lignin is dried and ashed in a muffle furnace, the remaining substances are silicate and ash, and the lignin content is the part that escapes during ashing [7]. The chemical composition degradation process of the sample is shown in Fig.1 below.

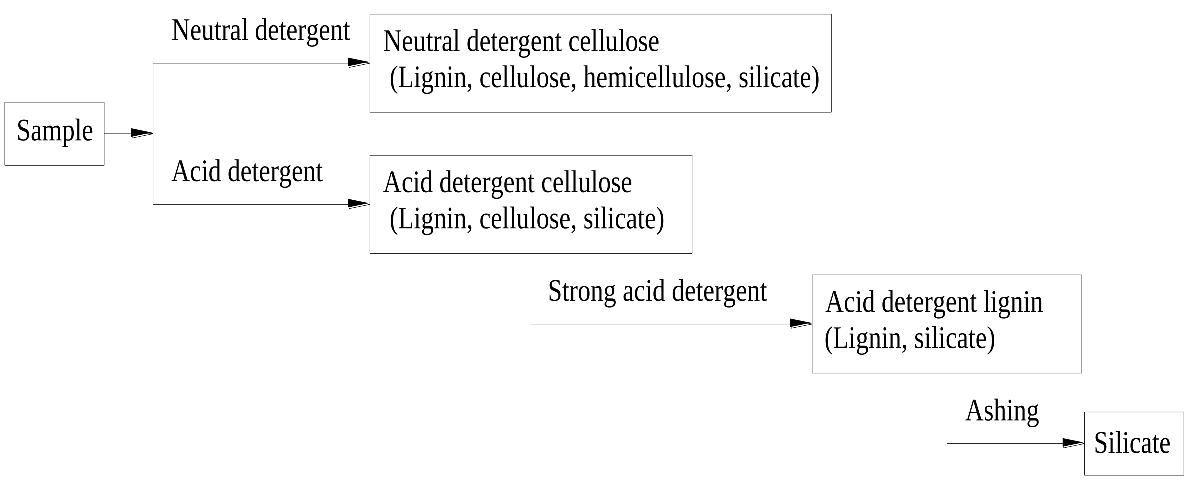


Fig 1: chemical composition degradation process of the sample

The Van Soest detergent fiber experiment was repeated 6 times, with test results shown in TABLE I.

ISSN: 0011-9342

Issue: 11 | Pages: 163 - 181

TABLE I. Experimental results of Van Soest detergent fiber experiment

Detergent fiber type	Treatment condition	Test number					
		1	2	3	4	5	6
Neutral detergent fiber	untreated	76.23	75.84	76.01	75.79	75.68	76.17
	Alkaline pretreatment	68.14	68.34	68.58	68.09	68.11	67.83
Acid detergent fiber	untreated	64.32	64.79	64.35	64.87	63.94	64.21
	Alkaline pretreatment	58.26	58.45	58.76	58.28	58.24	58.12
Strong acid detergent lignin	untreated	33.31	33.67	33.43	33.78	32.71	33.28
	Alkaline pretreatment	27.84	27.96	28.32	27.69	27.67	27.35
Silicate	untreated	7.27	7.73	7.29	7.82	6.67	7.23
	Alkaline pretreatment	7.49	7.69	7.93	7.44	7.46	7.18

According to the test principle, the lignocellulose content is calculated based on the following formula:

Hemicellulose content = neutral detergent fiber (DNF)-acid detergent fiber (ADF) (1)

Cellulose content = acid detergent fiber (ADF)-strong acid detergent lignin (ADL) (2)

Lignin content = strong acid detergent lignin (ADL)-silicate and ash (3)

The calculated lignocellulose content is shown in TABLE II.

Design Engineering

ISSN: 0011-9342

Issue: 11 | Pages: 163 - 181

TABLE II. Comparison of lignocellulose content of alkalized peanut straw and untreated peanut straw

Lignocelluloses type	Treatment condition	Test number						arithmetic mean
		1	2	3	4	5	6	
Hemicellulose	untreated	11.91	11.05	11.66	10.92	11.74	11.96	11.54
	Alkali pretreatment	9.88	9.89	9.82	9.81	9.87	9.71	9.83
Cellulose	untreated	31.01	31.12	30.92	31.09	31.23	30.93	31.05
	Alkali pretreatment	30.42	30.49	30.44	30.59	30.57	30.77	30.54
Lignin	untreated	26.04	25.94	26.14	25.96	26.04	26.05	26.03
	Alkali pretreatment	20.35	20.27	20.39	20.25	20.21	20.17	20.27

According to the test data, after alkalization, peanut straw has significantly reduced hemicellulose and lignin contents. Alkalization of peanut straw makes it easier for gastric juice and digestive enzymes of livestock digestive tract to infiltrate into the straw tissue, which improves the palatability while increasing feed intake and digestibility.

2.2 Influencing Factors

There are many factors influencing biomass single-hole compression molding, among which, the more important factors include straw crushing particle size, material moisture content, compressive stress, die hole diameter, and molding temperature.

Design Engineering

ISSN: 0011-9342

Issue: 11 | Pages: 163 - 181

2.2.1 Crushing Particle Size

Material crushing particle size is an important factor affecting compression molding quality. Xing Xianjun et al. (2016) conducted a single-hole test study on the biomass compression molding. The study showed that under smaller material crushing particle size, relaxation ratio is smaller with better molding block quality and lower energy consumption. The molding die used in the test has an inner diameter of 12mm. When the material crushing particle size is above 6mm, the molding energy consumption will be increased. When the material crushing particle size is less than 3mm or between 3mm~6mm, the relaxation ratio and energy consumption of the molding block are relatively low with small difference [8]. Considering crushing process cost of the material, this experiment uses crushing particle size of alkalized peanut straw as a factor that affects the molding, and sets the value range of this factor to 4mm~8mm.

2.2.2 Material Moisture Content

The material moisture content will directly affect the compression molding quality. In the case of too high moisture content, the relaxation ratio will be too large or even make material compression molding impossible; under too low moisture content, there will be increased friction between the materials and increased compressive strength, so higher molding pressure is needed, which causes increased energy consumption. In addition, moisture can lower the lignin softening point and promote its softening, which can also form a colloid with saccharides in biomass to improve the material adhesion, thereby improving the molding block quality. Hou Zhendong et al. (2010) conducted a research on the single-cavity curing and molding process of corn straws. The test results showed that under process conditions of molding pressure 60~90MPa, heating temperature 75~100℃, material moisture content 8%~12%, the molding blocks has the optimal quality [9]. Ji Aimin et al. (2017) conducted an experimental study on the ring die compression molding of straw-like biomass, and the test results showed that the molding effect is best under material moisture content of about 15% [10].

In this test, the crushed material moisture content of alkalized peanut straw is used as a factor that affects the molding, and the value range of this factor is set to 8%~16%. The moisture content level of the material is adjusted by crushing the peanut straw, drying, spraying and mixing the material, and sealing it with a sealed bag for 48 h. The sealed straw has uniform moisture content close to the natural drying state.

2.2.3 Compressive Stress

ISSN: 0011-9342
Issue: 11 | Pages: 163 - 181

Compressive stress is a key factor affecting biomass compression molding. Ma Fang (2017) studied the stress in peanut straw compression molding. In observation experiments on the compression relaxation ratio, it was found that as the compressive stress increases, the relaxation ratio gradually decreases. That is, under larger compressive stress, the compression block has more stable molding. When the compressive stress exceeds a certain value, there is no longer significant impact on the compression relaxation ratio. The compressive stress is between 60MPa~80MPa, which is in a suitable molding pressure range for peanut straw. In this test, the single mold hole was heated to improve the softening ability and bonding ability of lignin. Based on comprehensive consideration ofmolding block quality and energy consumption in molding, 60MPa is chosen as the maximum compressive stress.

2.2.4 Die Hole Diameter

Die hole diameter is also a major factor affecting biomass compression molding. Bai Xuewei (2014) conducted an experimental study on the compression and densification molding of corn straws. During the research process, die hole diameter was used as a factor for experimental analysis. The test results showed that density of the compression molding block would decrease with the increase of die hole diameter. When the die hole diameter was increased from 8mm to 14mm, the energy consumption per unit mass dropped rapidly from 130J/g to 10J/g, and when the die hole diameter continued to increase, the energy consumption remained at about 10J/g, leading to rapidly decreased molding quality [11].

In this test, the die hole diameter is used as a factor that affects molding, and three levels are set for the factor based on density, energy consumption and heat transfer, namely: 10mm, 12mm and 14mm. To achieve die hole diameter adjustment, compression mold should be changed, as shown in Fig. 2.

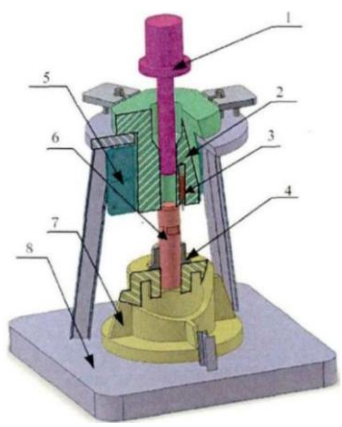
ISSN: 0011-9342

Issue: 11 | Pages: 163 - 181

Fig 2: Compression molds with die hole diameter at 10mm, 12mm and 14mm

2.2.5 Molding Temperature

The compressed straw pellet feed is mostly molded by flat die or ring die. Where, flat die molding equipment is popular thanks to its small size and low price. The friction between the straw fibers and that between the straw and the machine will generate a lot of heat during the operation of flat-die compression molding machine. After the machine startup, the temperature of the equipment and raw materials will gradually rise to about 100°C under the action of friction and maintain at the temperature level, thus softening the material, improving the adhesion and molding block quality. In this single-hole molding test, the single-hole mold temperature was adjusted to 100℃, and the temperature adjustment was achieved by self-made compression molding device, as shown in Fig.3. The outer surface of the molding mold was covered with two self-made heating rings 5 with a power of 150W, and then heat conductive silicone grease was spread between the heater and the mold. To accurately control the compression molding device temperature, it was connected to a temperature control system which was YL-6SD intelligent temperature controller in this experiment.



1. Compression bar2. Mold 3. Thermocouple 4. Adjusting screw nut

5. Heating ring 6. Crown bar 7. Base 8. Welding frame

Fig 3: Self-made compression molding device

2.3 Test Plan

During the test, the device shown in Fig.3 was placed on the workbench of the WDW-200

ISSN: 0011-9342

Issue: 11 | Pages: 163 - 181

universal material testing machine, and the compression bar 1 was clamped with the test machine fixture, so that the compression bar could move up and down with the beam to complete compression molding of peanut straw (Fig.4).

Fig 4: Single-hole compression molding test device for peanut straw

This test adopts three test factors with great impact on compression molding: the crushing particle size of peanut straw (x_1), moisture content (x_2) and die hole diameter (x_3). The crushing particle sizeof peanut straw has a value range of x_1=4mm~8mm, the moisture content has a value range of x_2=8%~16%, and the die hole diameterhas a value range of x_3=10mm~14mm. Due to the multiple non-linear regression relationship between the indexes of this test and multiple test factors, response surface methodology (RSM) was used in this test. According to the Central Composite test design principle, the relaxation ratio (y) of the block was used as the test indexes to perform3-factor 3-level response surface test analysis on crushing particle size (x_1), moisture content (x_2) and die hole diameter (x_3) of peanut straw. The test factor level coding is shown in TABLE III, and the test plan and results are shown in TABLE IV.

TABLE III. Level coding table for single-hole molding test factors of alkalized peanut straw

Code z_j	Crushing particle size (x_1)/mm	Moisture content (x_2)/%	Die hole diameter (x_3)/mm

Design Engineering

ISSN: 0011-9342

Issue: 11 | Pages: 163 - 181

-1	4	8	8
0	6	12	10
1	8	16	12
Δ_j	2	4	2

TABLE IV. Single-hole molding test plan and results of alkalized peanut straw

Test number	Crushing particle size (x_1)	Moisture content (x_2)	Die hole diameter (x_3)	Block relaxation ratio (y)
1	1	1	-1	1.3496
2	1	-1	1	1.3849
3	-1	1	1	1.3871
4	-1	-1	-1	1.1853
5	-1	0	0	1.1513
6	1	0	0	1.2327
7	0	-1	0	1.2142
8	0	1	0	1.2987
9	0	0	-1	1.1408
10	0	0	1	1.2614
11	0	0	0	1.1635

III. DATA ANALYSIS

Regression analysis was performed on the test data obtained in this molding test to

ISSN: 0011-9342

Issue: 11 | Pages: 163 - 181

determine the optimal combination of process parameters for single-hole molding of alkalized peanut straw.

3.1 Establishment of Mathematical Model

Regression analysis was performed on the resulting test data of this molding test using Design Expert software to obtain the regression mathematical model regarding the compression relaxation ratio (y) of the alkalized peanut straw:

$$y=1.1621+0.0407x_1+0.0423x_2+0.0603x_3-0.0010x_1x_2+0.0006x_1x_3+0.0002x_2x_3+0.0303x_1^2+0.0948x_2^2+0.0394x_3^2 \quad (4)$$

In the formula, $y$is the compression relaxation ratio; x_1 is the crushing particle size,mm; x_2 is the moisture content, %; x_3 is the die hole diameter, mm.To check significance of the regression equation, variance analysis is performed on formula (4), with analysis results shown in TABLE V.

TABLE V. Analysis of variance table

Difference Source	SS	df	MS	F-value	P-value	Significance
x_1	0.0561	1	0.0561	1092.88	0.0193	*
x_2	0.0364	1	0.0364	1177.71	0.0185	*
x_3	0.0125	1	0.0125	2398.94	0.0130	*
x_1x_2	0.0001	1	0.0001	0.46	0.6199	
x_1x_3	0.0007	1	0.0007	0.17	0.7498	
x_2x_3	0.0002	1	0.0002	0.013	0.9264	
x_1^2	0.0028	1	0.0028	733.97	0.0235	*

x_2^2	0.2013	1	0.2013	7172.28	0.0075	*
x_3^2	0.0014	1	0.0014	1240.76	0.0181	*
Regression model	0.3115	9	0.0346	3089.66	0.0140	*
Residual error	0.0031	1	0.0031			
Sum	0.3146	10				

As can be seen from TABLE V, $F_{回}$ =3089.66> ($F_{0.05}$(9, 1)=240.54), indicating that the compression relaxation ratio regression equation is significant at the level ofα=0.05.The coefficients of the regression model is subject tosignificance test, with F-value > 240.54, P-value < 0.05as significant items. The insignificant items are eliminated to derive regression equation of the compression relaxation ratio:

$$y=1.1621+0.0407x_1+0.0423x_2+0.0603x_3+0.0303x_1^2+0.0948x_2^2+0.0394x_3^2 \quad (5)$$

According to the test of the regression model coefficients, it is concluded that the various factors affect the compression molding relaxation ratio of alkalized peanut strawin the followingorder:

$$\text{moisture content}(x_2)>\text{die hole diameter}(x_3)> \text{crushing particle size}(x_1) \quad (6)$$

3.2 The Impact of Test Factors on Compression Relaxation Ratio

According to the regression model formula (5) of the compression relaxation ratio of alkalized peanut straw, ternary quadratic regression analysis is performed on the model usingDesign-Expert software and the relationship surface chart andcontour map about the factors and the compression relaxation ratio of the alkalized peanut straw are obtained.

Design Engineering

ISSN: 0011-9342

Issue: 11 | Pages: 163 - 181

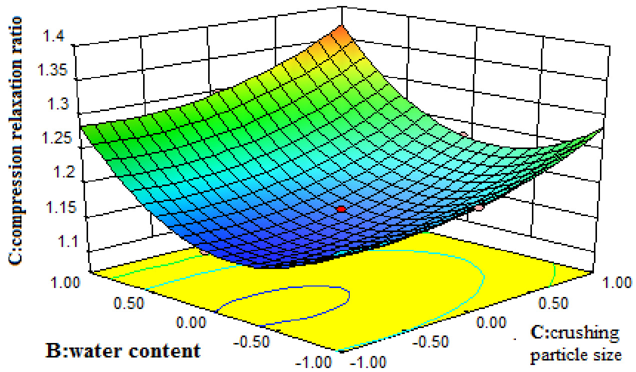


Fig 5: Response surface chart on water content crushing particle size and compression relaxation ratio

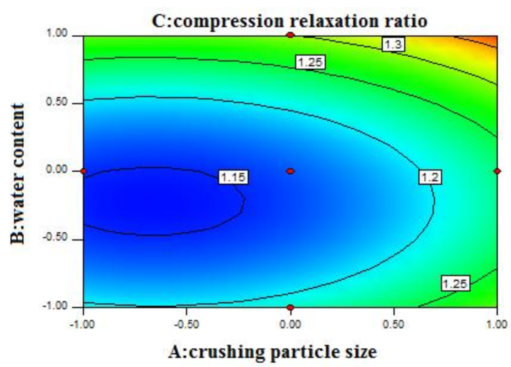


Fig 6: Contour map of moisture content crushing particle size and compression relaxation ratio

It can be seen from Fig. 5 and Fig. 6 that when the die hole diameter is fixed at 0 level (10mm), the compression relaxation ratio of alkalized peanut straw increases with the increasing crushing particle size. When the crushing particle size is between -1~0, the optimal value of compression relaxation ratio can be obtained; at the same time, the compression relaxation ratio first decreases and then increases with the increasing water content. When the water content is in the range of -0.5~0, the optimal value of compression relaxation ratio can be obtained. That is, the compression relaxation ratio is smaller under smaller crushing particle size; the compression relaxation ratio is smaller when the moisture content is closer to -0.5~0.

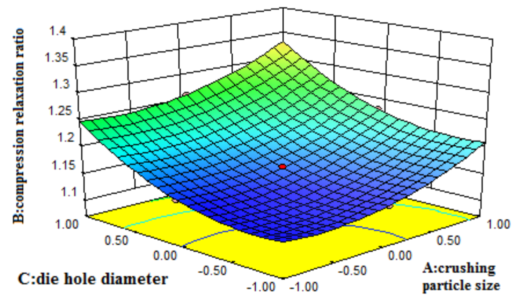


Fig 7: Response surface chart of die hole diameter crushing particle size and compression relaxation ratio

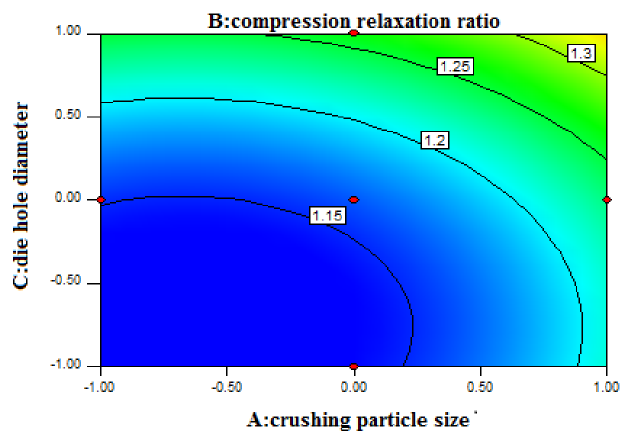


Fig 8: Contour map of die hole diameter crushing particle size and compression relaxation ratio

It can be seen from Fig. 7 and Fig. 8 that when the moisture content is fixed at 0 level (12%), the compression relaxation ratio of alkalized peanut straw increases with the increasing crushing particle size. When the crushing particle size is between -1~0, the optimal value of compression relaxation ratio can be obtained; at the same time, the compression relaxation ratio increases with the increasing die hole diameter. When the die hole diameter is within the range of 0~-1, the optimal value of compression relaxation ratio can be obtained. That is, the compression relaxation ratio is smaller under smaller crushing particle size; the compression relaxation ratio is smaller under smaller die hole diameter.

Design Engineering

ISSN: 0011-9342

Issue: 11 | Pages: 163 - 181

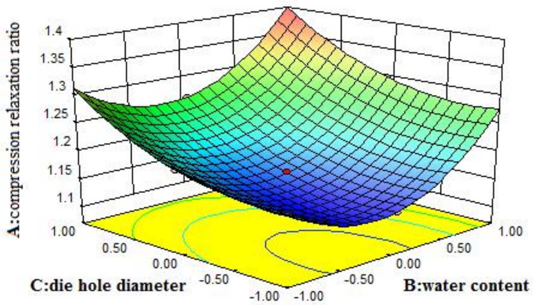


Fig 9: Response surface chart of water content die hole diameter and compression relaxation ratio

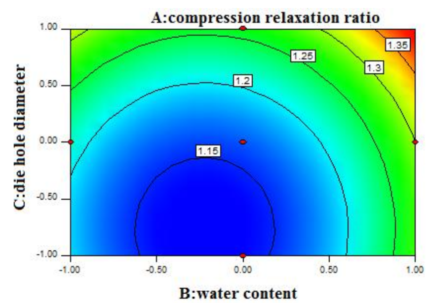


Fig 10: Contour map of moisture content die hole diameter and compression relaxation ratio

It can be seen from Fig. 9 and Fig. 10 that when the crushing particle size is fixed at 0 level (6mm), the compression relaxation ratio of alkalized peanut straw first decreases and then increases with the increasing moisture content. When the moisture content is in the range of 0.5~0, the optimal value of compression relaxation ratio can be obtained; at the same time, compression relaxation ratio increases with the increasing die hole diameter. When the die hole diameter is in range of 0~-1, the optimal value of compression relaxation ratio can be obtained. That is, the compression relaxation ratio is smaller when the moisture content is closer to -0.5~0; the compression relaxation ratio is smaller under smaller die hole diameter.

3.3 Optimization Analysis of Single-Hole Molding Process Parameters

To obtain the optimal process parameters for single-hole molding of alkalized peanut straw, it is necessary to optimize the regression equation based on multi-objective nonlinear optimization theory. First, determine the objective function of compression relaxation ratio (y), so that y reaches the minimum under the constraints. The objective function can be obtained as

ISSN: 0011-9342

Issue: 11 | Pages: 163 - 181

follows:

$$y=f(x_1,x_2,x_3)\rightarrow min \tag{7}$$

The value *Y* of the objective function should be greater than zero, and code value should be given to each test factor within the range limited by the factors in experimental design. After analysis, the constraint conditions are as follows:

$$\begin{cases} Y\geq 0 \\ -1\leq X_i\leq 1 \quad (i=1, 2, 3) \end{cases} \tag{8}$$

In the formula, *Y*—test index; X_i—impact factor; *i*—number of impact factors.

Design-Expert software is used to optimize and solve the established regression model, determine the optimal combination of process parameters for single-hole molding of alkalized peanut straw, as shown in TABLE VI.

TABLE VI. The optimal process parametersfor single-hole molding of alkalized peanut straw

Factor level (*X*)	**actual value of the factor (*x*)**	**Test index (*Y*)**
X_1=-0.49	x_1=5.12mm	
X_2=-0.33	x_2=10.68%	*Y*=1.1238
X_3=-0.87	x_3=8.26mm	

It can be seen from TABLE VI that after optimizing the compression relaxation ratio, a set of optimal parameter combinations is derived.That is, under crushing particle size 5.12mm, moisture content 10.68% and die hole diameter 8.26mm, the compression relaxation ratio of alkalized peanut straw can reach 1.1238. Considering actual processing situation, the 9FZ-25B claw disintegrator produced by Xinnong Agricultural Machinery Factory in Donggang City, Liaoning Province was used to crush the alkalized peanut straw.The crushed material has average particle size of around 5mm; the moisture content is adjusted to 10%~ 11%. To facilitate processing, it is determined that the flat die hole diameter is 8mm, the die hole length is 27mm, and the aspect ratio is 3.375 (Xiao Hongru et al., 2014; Kong Fanting, 2015), and the above flat die is installed toKL260 flat die pellet feed machine produced by Laizhou Wangfeng Machinery Co., Ltd., Shandong Province for testing. The results indicate that the pellet feed product has smooth surface (Fig. 11), with molding rate up to 98.33% and excellent molding quality.

Figure 11: Peanut straw pellet feed

IV. CONCLUSION

In this paper, alkalization of peanut straw significantly reduces the content of hemicellulose and lignin, improves palatability of peanut straw, and increases feed intake and digestibility. Based on analysis of the influence of straw crushing particle size, material moisture content, compressive stress, die hole diameter and molding temperature on compression molding, the maximum stress is set to 60MPa and the test temperature is set to 100℃ for single-hole compression molding test withblock relaxation ratio as the test index and crushing particle size, moisture content and die hole diameter of peanut straw as the test factors. The test results are subjected to regression optimization analysis to obtain the optimal combination of process parameters: crushing particle size 5.12mm, moisture content 10.68%, die hole diameter 8.26mm, and the compression relaxation ratio of alkalized peanut straw can reach 1.1238 at this time. To facilitate processingand production, it is determined that the average straw crushing particle sizeis about 5mm,the moisture content is between 10%~11%,the flat die hole diameter is 8mm, the die hole length is 27mm.The peanut straw pellet feed produced by such combination of process parameters has smooth surface, with molding rate up to 98.33%.

ACKNOWLEDGEMENT

The author thanks the helping of two corresponding authors Prof. Congqing Shao and Ph.D. Eng Zhongyu Chen. The study was sponsored by Qing Lan Project and the Yancheng Polytechnic College Introducing High-level Talents Scientific Research Project (GYYJRC2018-1).

REFERENCES

[1]LiuTaiyu, Guo Xiao (2003) The studies on rational utilzation for green fodder of peanut vite. Chinese Agricultural Science Bulletin 19(5): 17-19

[2] Zhang Feng, Wu Zhanjun, Liu Xiaohu, Ma Shulin, Wang Kun, Li Kuiying, Zuo Xiaolei (2009) Nutritional characteristics of sweet potato and peanut seedlings and their application in dairy farming. China Dairy Cattle 5: 58-60

[3] Chen Yan, Wang Zhisheng, Zhang Xiaoming, Wu Fali, Zou Huaguo (2015) Analysis of the nutritional components and feeding values of commonly used roughages. Acta Prataculturae Sinica 5: 117-125

[4] Ma Fang (2017) Mechanisim and test research on peanut strawstalk feed molding. Shenyang Agricultural University

[5] Ma Qiang, Dun Baoqing, Xi Yajun, Wang Zhi, Chen Chaoru, Lu Ming, Li Guiying (2014) Effects of alkali treatment on component and structure and enzyme sac-charifyingefficiency of sweet sorghum bagasse. Acta Agronomica Sinica 9: 1604-1611

[6] Liu Kaiyu, Zhang Yonggen, Xin Hangshu, Li Yang, Li Chunlei, Li Xinxin (2014) Studies on different processing rice straw nutrients and rumen degradability. Chinese Journal of Animal Science 50(7): 57-61, 101

[7] Song Jinchang, NiuYibing (2012) Feed analysis and feed quality detection technology. Beijing: China Agricultural Science and Technology Press. ISBN: 9787511609526

[8] Xing Xianjun, Li Tao, Ma Peiyong, Hu Yunlong, Sun Yadong, Li Hui (2016) Experimental study of hot molding of densified biofuel. Acta Energiae Solaris Sinica 37(10): 2660-2667

ISSN: 0011-9342

Issue: 11 | Pages: 163 - 181

[9] Hou Zhendong, Tian Xiaoyu, Xu Yang (2010) Effect of densification processing on physical quality and mechanical properties of corn stover. Transactions of the Chinese Society for Agricultural Machinery 41(5): 86-89

[10] Ji Aimin, ZhaoRongxuan, Li Haiying, Zhang Ze (2017) Study on the influencing factors of straw biomass pressure forming process design of the divided no-till wheat planter. Journal of Agricultural Mechanization Research 39(2): 220-225

[11] Bai Xuewei (2014) Process parameters optimization and mechanical simulation in densification of corn stalk powder. Shenyang Agricultural University

[12] Herak D., A. Kabutey, R. Choteborsky, M. Petru, R. Sigalingging. (2015) Mathematical models describing the relaxation behavior of Jatropha curcas L. bulk seeds under axial compression. Biosystems Engineering 131: 77-83

[13] Jachimczyk R. M. E. 2015. Rheological prorerties of a straw layer. Original Contribution 54: 19-27

[14] TabilL., P. Adapa, M. Kashaninejad. (2011) Biomass feedstock pre-processing-part 2: densification. Biofuel's Engineering Process Technology 19: 439-464