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OPTIMIZATION OF PROCESSING FORMULA OF TARO CAMLLIA OIL COOKIES BY RESPONSE SURFACE METHODOLOGY

The object of this research is taro that rich in nutrition, and camellia oil contains polyunsaturated fatty acids. In order to improve their utilization value, taro powder and camellia oil were added into cookies. Using low gluten flour as raw material, taro powder, camellia oil, soft sugar, egg liquid and Siraitia grosvenorii honey as auxiliary materials, the processing formula of taro camellia oil cookies was optimized by response surface methodology. Based on sensory evaluation standard and single factor experiment, Box-Behnken experiment design was carried out on the formula of taro camellia oil cookies. The results showed that low gluten flour 50.0 g, camellia oil 41.0 g, taro powder 35.2 g, egg liquid 35.0 g, soft sugar 18.0 g, Siraitia grosvenorii honey 3.1 g, heating temperature 150 °C, baking for 15 min, the sensory score of taro camellia oil cookies was the highest. Under this process, the prepared cookies have the best taste, and all the indexes meet the national standards of China. The cookies made with the experimental formula had intact appearance, crisp taste, clear lines, fine organization, aroma of taro, moderate sweetness, and unique flavour of taro and Siraitia grosvenorii.

Optimized processing formula of taro camllia oil cookies will be of interest to other countries because of taro camellia oil cookies not only had rich nutrients and high nutritional value, but also met the needs of consumers and the market, and had a good market prospect.

Keywords: *taro powder, camellia oil, Siraitia grosvenorii honey, cookie preparation, response surface.*

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1. Introduction

Taro is rich in starch, crude fiber, crude protein and many trace elements, and its zinc and calcium contents are higher than those of wheat [1, 2]. The types of amino acids in taro are relatively complete, the proportion is relatively balanced, and the content of lysine is also relatively rich, which can supplement the deficiency of lysine in human body [3]. Dietary fiber can promote intestinal peristalsis and delay carbohydrate digestion and absorption. Polysaccharide can enhance human immune function, improve human immunity, and reduce the digestion and absorption of fat in gastrointestinal tract through interaction with cholate, which has the effect of reducing fat [4, 5]. Taro has high nutritional value and wide distribution of resources. Although the output of taro in China ranks first in the world, it is not fully developed and utilized. People lack the understanding of taro processed products. At present, there are few taro processed products on the market [6, 7]. Taro products developed in recent years included:

– preserved taro [8];
– taro noodles [9, 10];
– taro biscuits [11];
– taro bread [12].

The medicinal value of camellia oil has been studied and recorded in China since ancient times, and it has great edible value. Camellia oil contains tea polyphenols, squalene, camellia glycosides, fatty acids easy to be absorbed by human body, as well as a variety of vitamins, minerals and other substances [13]. It is found that camellia oil contains linoleic acid and linolenic acid in proportion to human intake requirements [14]. In addition, camellia oil also has the functions of reducing «three highs» (blood glucose, blood lipid and blood pressure) and regulating immunity [15, 16]. Camellia oil has such excellent therapeutic value that it is mainly sold as high-grade edible oil in the market. The products of this consumption mode are too single and the relative consumption range is small.

With the completion of a well-off society in an all-round way and the increase of people's health awareness, consumers put forward new demands for nutrition and health of cookie products. Traditional cookies are prohibitive to some consumers because of their high oil and sugar content. Camellia oil was used to replace butter, taro powder was used to replace some flour, and Siraitia grosvenorii honey was used to replace some soft white sugar to explore the influence of raw and auxiliary materials of taro tea oil cookies on the quality of cookies.

A cookie with taro fragrance, sweet taste and more crude fiber was developed.

Thus, *the object of this research* is taro that rich in nutrition, and camellia oil contains polyunsaturated fatty acids.

The aim of this research is to develop cookies with low sugar, low oil and high nutritional value. At the same time, it provides an important direction for the deep processing of camellia oil and taro powder.

2. Research methodology

2.1. Test material

Areca taro, low gluten flour and eggs: commercially available; Camellia oil: Zhejiang Dongfang Tea Technology Co., Ltd (China); Siraitia grosvenorii honey: Guilin Monk Fruit corp Co., Ltd (China); Cotton sugar: Angel yeast Co., Ltd (China).

2.2. Instruments and Equipments

DHG-9140A electric heating constant temperature blast drying oven: Shanghai Qixin Scientific Instrument Co., Ltd (China). YDX-90 oven: Shanghai Honglian Machinery and Electrical Appliance Manufacturing Co., Ltd (China). J1000Y electronic balance: Changshu Shuangjie Testing Instrument Factory (China). TA.XTplus physical property tester: Stable Micro System, UK. Agitator: Hefei Rongshida Small Household Appliances Co., Ltd (China). MB90 moisture tester: Aohaosi Instrument Co., Ltd (China). DFY-600 high speed universal crusher: Wenling Linda Machinery Co., Ltd (China).

2.3. Test method

2.3.1. Preparation of taro powder. Taro powder was prepared according to the hot air drying method of Zhang Peng [17]. The fresh taro was washed, peeled and cut into 4–5 mm taro slices. The hot air drying oven was set at 55–60 °C and the drying time was 4–5 h. The above taro slices were put into it for drying. The dried taro chips were put into the crusher and crushed by setting the mode to 200 mesh. The taro powders obtained were sieved and saved for standby.

2.3.2. Basic formula. The total amount of mixed powder (taro powder+low gluten flour) was 85 g, camellia oil was 50 g, egg liquid was 30 g, soft white sugar was 18 g and Siraitia grosvenorii honey was 2 g.

2.3.3. Process flow: weighing → emulsification → batter modulation → forming → baking → cooling → finished product.

2.3.4. Cookie making process. Key points of operation: accurately weigh various raw and auxiliary materials for standby. Sift taro flour and low gluten flour through 60 mesh sieve respectively and set aside. Add a small amount of soft white sugar and camellia oil into the egg liquid several times in order, beat it to the emulsion state and set aside. Add the mixed powder into the emulsified egg liquid and stir it to make it fully mixed. Do not stir too much to avoid gluten, which will affect the expansion of cookies in the baking process. Put the prepared batter into the piping bag and squeeze the cookies into a complete shape with clear patterns with balanced force. Adjust the upper and lower fire of the oven to 150 °C and bake for 15 min. Cool at room temperature.

2.4. Test contents

2.4.1. Single factor test. The baking temperature is 150 °C and the baking time is 15 min. The addition amount of camellia oil, the mass ratio of mixed powder and the addition amount of Siraitia grosvenorii honey were selected as the experimental factors. The effects of camellia oil (35, 40, 45, 50, 55 g), taro powder (25, 30, 35, 40, 45 g) and Siraitia grosvenorii honey (2.0, 2.5, 3.0, 3.5, 4.0 g) on the quality of cookies were investigated.

2.4.2. Response surface Optimization test. On the basis of single factor test, the test scheme is designed by box Behnken design, and then the test results are analyzed by design expert 8.0.6 software to further optimize the addition amount of taro powder, camellia oil and Siraitia grosvenorii honey in the cookie formula. See Table 1 for test factors and level design.

Table 1

Factors and levels of experimental variables

Level	Factor		
	A: Camellia oil addition, g	*B*: Addition amount of taro powder, g	*C*: Addition amount of Siraitia grosvenorii honey, g
–1	35	30	2.5
0	40	35	3.0
1	45	40	3.5

2.4.3. Sensory evaluation of cookies. The members of the evaluation team were composed of 8 students majoring in food. They would conduct sensory evaluation on the quality of cookies through the requirements of color, smell, organization and taste. The evaluation score was the percentage system, and the result was the average value. See Table 2 for specific evaluation criteria.

Table 2

Sensory evaluation form of cookies

Index	Features	Index score
Color	The surface is yellowish brown, the color is uniform and full, and there is no burnt paste	16–25
	The surface color is brownish yellow, with a little burnt paste and spots on the surface	8–16
	The surface color is uneven, yellowish brown and over burnt	0–8
Smell	The unique aroma of taro is the same	16–25
	The fragrance is not strong and there is no peculiar smell	8–16
	No fragrance and obvious peculiar smell	0–8
Organization	Porous, fine and uniform pores	16–25
	Secondary hole, relatively uniform	8–16
	The hole is large and uneven	0–8
Taste	The taste is crisp, refreshing and sweet	16–25
	The taste is crisp and not greasy	8–16
	The taste is not greasy and crisp	0–8

2.4.4. Determination of physical, chemical and microbiological indexes. The quality inspection of taro camellia oil cookies is carried out in strict accordance with the national food safety standards. The experimental methods are shown in Table 3.

Table 3

Test items and methods

Index	Project	Determination method
Physical and chemical indexes [18–26]	Protein, g/100 g	GB 5009.5-2016
	Fat, g/100 g	GB 5009.6-2016
	Water content, %	GB 5009.3-2016
	Acid value, mg/g	GB 5009.227-2016
	Peroxide value, g/100 g	GB 5009.229-2016
	Carbohydrates, g/100 g	GB 5009.7-2016
	Sodium, mg/g	GB5009.91-2017
	Total sugar, g/100 g	GB/T 20977-2007
	Coarse fiber, g/100 g	GB/T 5009.10-2003
Microbial indexes [27–29]	Escherichia coli, CFU/g	GB 4789.3-2016
	Total number of colonies, CFU/g	GB 4789.2-2016
	Mould, each	GB 4789.15-2016

2.4.5. Texture measurement. The texture characteristics of cookies were measured by texture analyzer. With reference to Zhang Qiang and other methods, slightly modified, the probe was P/36R [30]. The parameter measurement mode is:

– the speed before/after measurement is 4 mm/s;
– the measurement speed is 1.5 mm/s;
– the residence time between two compressions is 5 s;
– the degree of compression is 60 %.

The hardness (g), adhesion (g·s) and chewability of the sample were measured. Each sample was measured three times and the average value was taken. The results are shown in Table 4.

Table 4

Analysis of variance of regression equation

Variance source	Sum of squares	Freedom	Mean square	*F* value	*P* value	Significance
Model	155.23	9	17.25	12.93	0.0014	**
A	16.99	1	16.99	12.74	0.0091	**
B	4.81	1	4.81	3.60	0.0995	*
C	0.40	1	0.40	0.30	0.6028	–
AB	0.78	1	0.78	0.59	0.4686	–
AC	0.39	1	0.39	0.29	0.6052	–
BC	0.16	1	0.16	0.12	0.7424	–
A^2	64.13	1	64.13	48.07	0.0002	**
B^2	36.59	1	36.59	27.42	0.0012	**
C^2	18.18	1	18.18	13.62	0.0077	**
Residual term	9.34	7	1.33	–	–	–
Spurious term	5.69	3	1.90	2.06	0.2462	–
Pure error term	3.65	4	0.91	–	–	–
Total error term	164.57	16	–	–	–	–
R^2	0.9432	–	–	–	–	–
R^2_{adj}	0.8703	–	–	–	–	–

Note: * – indicates significant difference ($P<0.05$); ** – indicates extremely significant difference ($P<0.01$)

2.4.6. Data analysis. The statistical analysis of single factor test results, response surface test design and result analysis adopt excel 2010 software and design expert V8.0.5 software for analysis and processing.

3. Research results and discussion

3.1. Single factor test analysis

3.1.1. Effect of camellia oil addition on the quality of cookies. The addition of camellia oil had a certain effect on the molding and crispness of cookies. It could be seen from Fig. 1 that when the amount of camellia oil was 40 g, the cookies had complete appearance, delicate organization and the best taste.

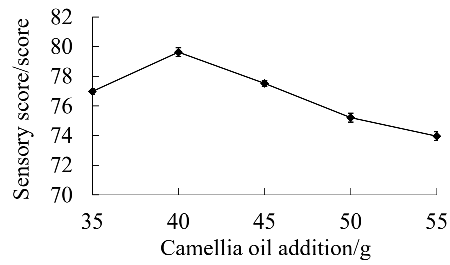

Fig. 1. Effect of camellia oil addition on the quality of cookies

When the addition amount was more than 40 g, the crispness of cookies was good, but too much oil would make the dough moist and difficult to form, and the oil would be seriously removed, which will lead to the collapse of cookies after baking, bubbles on the surface and affect the appearance of cookies. When the amount of camellia oil was less than 40 g, the dough was dry and loose, which was difficult to operate during cookie shaping, and there was edge cracking after baking. To sum up, the optimum amount of camellia oil was 40 g.

3.1.2. Effect of taro powder addition on the quality of cookies. Taro powder could dilute the gluten protein in the dough and reduce the hardness of cookies. It could be seen from Fig. 2 that when the addition amount of taro powder was 30 g, the tissue was fine, the taste was crisp and loose, and its sensory evaluation score was the highest. When the addition amount of taro powder was less than 30 g, the taro taste was light and the dough was not easy to form. With the increase of the content of taro powder, the inside of cookies became crisp and loose, and the taste of taro became more and more strong. However, too much addition maked the strength of dough too low, the dough was not easy to form, and the roughness and sandy feeling of the entrance were enhanced. Finally, the optimum amount of taro powder was 30 g.

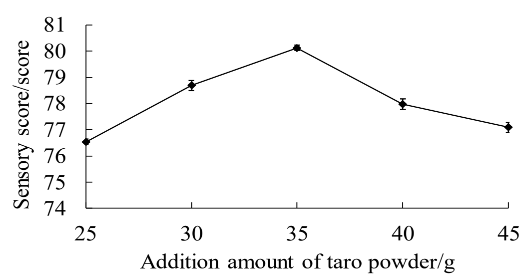

Fig. 2. Effect of taro powder addition on the quality of cookies

3.1.3. Effect of Siraitia grosvenorii honey addition on the quality of cookies. The addition of Siraitia grosvenorii honey could sweeten the entrance of cookies and prevent dental caries to a certain extent. It could be seen from Fig. 3 that when the addition amount of Siraitia grosvenorii honey was 3 g, the sweetness of cookies was moderate, there was obvious sweet recovery, the duration was long and the taste was good. When the addition of Siraitia grosvenorii honey was less than 3 g, the sweet taste of cookies was very weak and the return to sweetness was not obvious.

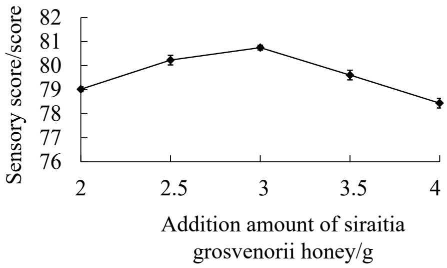

Fig. 3. Effect of Siraitia grosvenorii honey addition on the quality of cookies

When the content of Siraitia grosvenorii honey was higher than 3 g, the sweet recovery was obvious, and it was too sweet and greasy. Finally, 3 g Siraitia grosvenorii honey was determined as the best addition.

3.2. Response surface optimization test analysis

3.2.1. Establishment of regression model and significance analysis. A total of 17 groups of tests including $X1$ (camellia oil addition, g), $X2$ (taro powder addition, g), $X3$ (Siraitia grosvenorii honey addition, g) and Y (sensory score/score) were tested and scored according to the factor level table designed in Table 1 and the evaluation criteria in Table 2. The results are shown in Table 5.

Design expert 8.0.6 software was used to fit the cookies made in Table 5 according to the sensory scoring results, and the multiple regression equation was obtained:

$$Y=+82.36+1.46\cdot X1+0.78\cdot X2-0.22\cdot X3+0.44\cdot X1\cdot X2-$$
$$-0.31\cdot X1\cdot X3-0.20\cdot X2\cdot X3-3.90\cdot X1^2-2.95\cdot X2^2-2.08\cdot X3^2.$$

The variance and significance of the regression model were analyzed through Table 5. The results showed that the model $P=0.0014<0.01$, and the mismatch term $P=0.2462>0.05$. The former was significant, and the latter was not significant, indicating the effectiveness of the model. The judgment coefficient $R^2=0.9432$, which was close to 1, indicating that the goodness of fit of the model was high; the correction determination coefficient $R^2_{adj}=0.8703$, expressed as the response value change of 87.03 %, which could be used to predict the technological formula of taro camellia oil cookies. In the sensory model, primary item $X1$, secondary items $X1^2$, $X2^2$ and $X3^2$ had a significant impact on the comprehensive score of cookies ($P<0.01$), primary item $X2$ had a significant impact on the comprehensive score of cookies ($P<0.05$), while primary item $X3$ and each interactive item had no significant impact on the comprehensive score of cookies ($P>0.05$). The size of F value could be used as the basis for judging the primary and secondary influence of various factors on the sensory score of cookies [31]. The greater the F value, the greater the impact. The order was $X1>X2>X3$, that was, the addition of camellia oil had a great influence on the sensory score, followed by taro powder, and the addition of Siraitia grosvenorii honey has the least influence.

Table 5

Design and results of response surface central composite test

Experiment number	$X1$	$X2$	$X3$	Total score Y/score
1	35	35	3.5	73.91
2	45	40	3	77.79
3	35	40	3	74.67
4	45	35	3.5	76.85
5	35	30	3	74.11
6	40	30	2.5	75.74
7	40	40	3.5	78.53
8	40	35	3	82.56
9	40	35	3	81.12
10	45	35	2.5	79.47
11	45	30	3	75.49
12	40	30	3.5	77.24
13	40	35	3	81.68
14	40	35	3	82.94
15	40	35	3	83.49
16	40	40	2.5	77.82
17	35	35	2.5	75.28

The response surfaces of the interaction between camellia oil, taro powder and Siraitia grosvenorii honey on the sensory quality of taro camellia oil cookies are shown in Fig. 4.

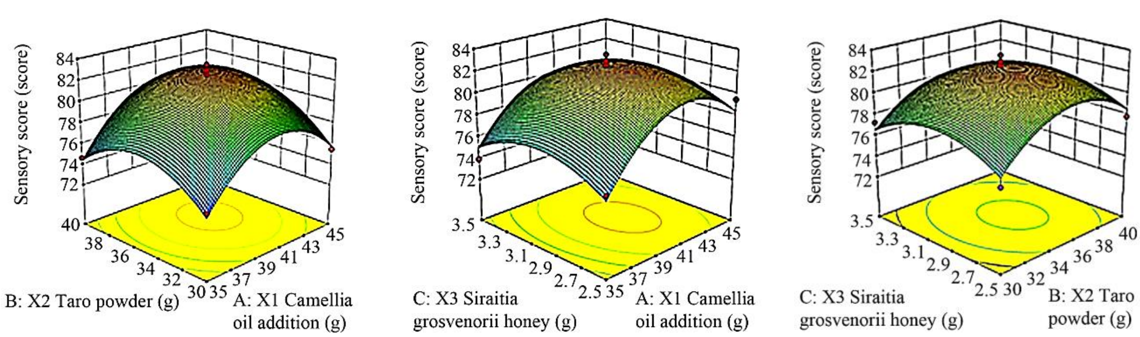

Fig. 4. Response surface methodology for the interaction of various factors on sensory quality of taro camellia oil cookies: *a* – the interaction of taro powder and camellia oil addition; *b* – the interaction of Siraitia grosvenorii honey and camellia oil addition; *c* – the interaction of Siraitia grosvenorii honey and taro powder

From the curved surface bending degree, it is possible to see the influence of the two variables on the dependent variable. The greater the inclination, the steeper the slope, the greater the influence; on the contrary, the smaller the impact. The size of the interaction could be judged by the shape of the contour line. The contour line tended to be oval, and the greater the interaction is; if it tended to be circular, the interaction was smaller [32]. It could be seen from Fig. 4 that $X1$ and $X2$ had a greater impact on sensory scores than $X2$ and $X3$. The projection of the interaction of various factors in Fig. 4 was oval. The addition of camellia oil, taro powder and Siraitia grosvenorii honey had a significant impact on the sensory score of cookies. In conclusion, the results of response surface analysis were consistent with the significance analysis.

3.2.2. Confirmatory test results. The response surface test predicted that the best technological formula of cookies was that the sensory score was 82.32 g when the amount of camellia oil was 40.84 g, taro powder was 35.18 g and Siraitia grosvenorii honey was 3.09 g. In order to facilitate the practical operation, the optimal parameters were adjusted to 41.0 g camellia oil, 35.2 g taro powder and 3.1 g Siraitia grosvenorii honey. The experiments were repeated for three times. The sensory bisection and predicted value were ±1.43. The measured results were stable and verified the reliability of the model.

3.3. Texture measurement results. The texture of the product obtained under the optimal formula was analyzed from three aspects: hardness, adhesion and chewiness. The results are shown in Table 6.

Table 6

TPA parameters of taro camellia oil cookies

Hardness, g	Adhesion, g·s	Chewiness
2328.89	–0.31	200.07

3.4. Cookie quality inspection

The quality inspection of taro camellia oil cookies was carried out in strict accordance with the national food safety standards. The results and limit values are shown in Table 7.

Table 7

Quality test results of taro camellia oil cookies

Index	Project	Result	National standard limit value
Physical and chemical indexes	Protein, g/100 g	9.47	≥4.0
	Fat, g/100 g	27.7	≥16.0
	Water content, %	1.28	≤4.0
	Acid value, mg/g	1.2	<5
	Peroxide value, g/100 g	0	<0.25
	Carbohydrates, g/100 g	50.4	–
	Sodium, mg/g	165	–
	Total sugar, g/100 g	12	≤40.0
	Coarse fiber, g/100 g	1.1	–
Microbial index	Escherichia coli, CFU/g	<10	<102
	Total number of colonies, CFU/g	<10	<105
	Mould, each	<10	<50

Referring to the corresponding provisions in GB 7100-2015 national standard for food safety – biscuits and GB/T 20980-2007 biscuits, the physical and chemical indexes and microbial indexes of taro camellia oil cookies in Table 7 meet the requirements of relevant national standards.

Although these cookies have high nutritional value, taro is a local characteristic food. Due to the influence of raw materials and regions, it has certain seasonality and single origin. Compared with traditional cookies, these cookies have low oil, low sugar and higher nutritional value, which meet the consumption demand of modern people in pursuit of health. The research results are helpful to enrich the deep processing forms of taro and have practical significance for the development and utilization of taro resources.

4. Conclusions

On the basis of single factor experiment, through Box Behnken experimental design, the models of sensory score of taro camellia oil cookies and the amount of camellia oil, taro powder and Siraitia grosvenorii honey were obtained. Finally, the best formula of taro camellia oil cookies was determined as follows: when the amount of low gluten flour was 50.0 g, camellia oil was 41.0 g, taro powder was 35.2 g, egg liquid was 35.0 g and Siraitia grosvenorii honey was 3.1 g, the sensory score of taro camellia oil cookies was the best under the baking condition of 150 °C for 15 min.

The cookies made with the experimental formula had intact appearance, crisp taste, clear lines, fine organization, aroma of taro, moderate sweetness, and unique flavor of taro and Siraitia grosvenorii honey. Compared with traditional cookies, taro camellia oil cookies had high cost, low fat content, strong health care function and high nutritional value. The skin from the production of taro camellia oil cookies could be used to extract crude fiber, so as to increase the cellulose content of cookies, meet the health needs of modern consumers, and improve the added value of raw materials.

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STUDY ON APPLICATION OF PUMPKIN SEED PROTEIN ISOLATE IN SAUSAGE PRODUCTION PROCESS

The object of the research is sausage added with pumpkin seed protein isolate. Recently, plant proteins such as soybean protein and peanut protein are widely applied in meat products. Plant proteins have a lower price and less fat than animal meat, which is benefit for human health. Pumpkin seed protein is one of the new plant proteins, which contained balanced amino acids for human beings, was attracted an increasing interest in food industry. In this study, a new type of sausage was developed by single-factor experiments and orthogonal test. According to the single factor results, the added amount of the pumpkin seed protein isolate (1.5 g/100 g, 2.25 g/100 g, 3.0 g/100 g), lean meat (60 g/100 g, 70 g/100 g, 80 g/100 g), cooking time (35 min, 40 min, 45 min), and baking time (2.5 h) were determined to do the orthogonal test. The orthogonal test showed that the addition amount of pumpkin seed protein isolate had the greatest impact on the sausage quality, followed by the cooking time, and the addition amount of lean meat. The optimal production conditions were pumpkin seed protein isolate of 1.5 g/100 g, lean meat of 80 g/100 g, cooking time of 45 min, and baking time of 2.5 h. Under this condition, the sensory score reached 8.5, and the content of moisture, ash, protein, and fat were 51.16 g/100 g, 2.26 g/100 g, 15.22 g/100 g, and 23.15 g/100 g, respectively. This study can provide a fundamental knowledge for the application of pumpkin seed protein isolate in sausages.

Keywords: *food industry, meat products, sausage, pumpkin seed protein isolate, orthogonal test.*

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1. Introduction

The price of meat products, such as meat patties, sausages, and meatballs, are usually high [1]. In the making process of meat products, the formation of protein three-dimensional mesh structure, and its ability to effectively absorb oil, water, and other food components plays a vital role in the structure and the quality of the final product. The formation process of muscle protein gel is divided into three steps:

1) the dissolution of protein with high salt concentration and depolymerization of myofibrillar protein;

2) the partial folding with temperature;

3) through the combined action of hydrogen bond, disulfide bond, electrostatic interaction forces and hydrophobic interaction forces, the areas that have been folded are further aggregated to form a three-dimensional mesh structure [2].

In order to increase the output of the final product, reduce production costs, and improve the properties related to product quality, meat processing enterprises usually want to add a certain amount of plant protein to the product formula [3]. Plant proteins have a lower price and less fat than animal meat, which is benefit for human health. Soybean protein is the major source used in meat products as a functional ingredient [4]. Besides soybean, the utilization of other plant proteins like pea protein, flaxseed protein, pumpkin seed protein, and sunflower seed protein are increased in food products. Previous work showed that 20 % of pork meat can be replaced by pea products of pea protein isolate (PPI), pea low moisture extrudates (LME), and pea high moisture extrudate (HME) in emulsified cooked