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Optimization of Low-Sugar Polygonatum Jam Production Process by Response Surface Methodology

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Abstract. Polygonatum jam was used as the main raw material in this experiment, on the basis of the single-factor experiment, the interaction of xylitol, citric acid, $CaCl_2$, low-methoxy pectin was investigated according to Box-Benhnken design. The sensory score and textural properties were used as the indicators to determine the optimum parameters of the low-sugar polygonatum jam. The results showed that the ideal parameters to product low-sugar polygonatum jam were as follows: xylitol 9.28%, citric acid 0.05%, $CaCl_2$ 0.51%, and low-methoxy pectin 1.02%. The sensory index of verification experiment was 95.7 which was basically consistent with the theoretical value 95.1.

Keywords: Low-sugar, polygonatum, textural properties, response surface methodology

1 Introduction

Polygonatum sibiricum, a genus of the family Liliaceae, which includes Polygonatum kingianum Coll.Et Hemsl, Polygonatum sibiricum Red and Polygonatum cyrtonema Hua. There are more than 60 species of them among the world and distributed throughout the temperate Northern Hemisphere such as China, Japan, Korea, India, Russia, Europe and North America [1]. Most of Polygonatum plants grow in moist and shady places forests or bushes with thick and fertile soil. There are 31 species of Polygonatum sibiricum in China, which are widespread in vast areas except the southern tropics. The earliest recording of the use of Polygonatum plants is in The Chinese pharmacopoeia, and the polygonatum sibiricum is considered to be the "Top grade" herbs in *Shennong Bencao Jing* (100 BCE-200 CE, Qin and Han Dynasties) due to their life span-prolonging effect and nontoxicity[2-3],which is a kind of commonly used Chinese herbal medicines for the 2015 edition of the *Chinese Pharmacopoeia* [4]. Polygonatum sibiricum have a variety of pharmacological properties such as anti-diabetic [5], anti-inflammatory [6], anti-atherosclerosis [7] and bone protective effects [8]. Polygonatum plants are also a kind of medicinal and edible homologous plant which are widely used by the people in the folk, and the Polygonatum cyrtonema Hua which in the Jiuhua Mountain area of Anhui Province. With the gradual deepening of pharmacological effects, chemical constituents and clinical research of Polygonatum, the new drug research pays more attention on the active parts and active ingredients [9].

Polygonatum plants are also used as functional food in various ways. The rhizomes are often cooked with meat or porridge, made into tea or medicated wine and consumed as fruit or vegetables. The young leaves and stems are also used as vegetables in some places [10-11]. It can be processed into nourishing foods, such as the Polygonatum Candied Fruit, the Polygonatum Tonic, the Polygonatum Oral Liquid, the Polygonatum Granules, etc. This experiment makes full use of Polygonatum sibiricum to develop a convenient and easy-to-eat product, a low-sugar Polygonatum jam, which expands the variety of Polygonatum food. For some special populations such as those with high blood pressure or diabetes, there is an inevitable concern about the amount of sucrose in the jam products [12-14]. As a functional sweetener, xylitol can participate in human metabolism after entering the bloodstream. It can penetrate into cells without insulin, and has a fast metabolic rate, which will not cause blood sugar to rise. It is a nutrient type sucrose substitute suitable for diabetic patients. Xylitol also results in benefiting the liver, anti-caries, weight loss, etc. [15-17]. In addition, Polygonatum sibiricum is often processed by repeated cooking and

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drying until the rhizomes become black, soft and sweet in order to enhance their tonic function and avoid throat irritation. This experiment took Polygonatum jam as the main raw material, added xylitol, low-methoxy pectin and citric acid, etc. to make low-sugar Polygonatum jam with good taste and rich nutrition, in order to enhance the nutritional function of the products. On the basis of the single-factor experiment, the optimal process formula of Polygonatum jam was optimized by Box-Behnken experiment, and the nutritional value of Polygonatum was fully utilized to develop a low-sugar Polygonatum jam that combines deliciousness and nutrition. It not only solves the problem of excessive sugar content in jam products for exceptional populations, but also has important significance for discovering and developing Chinese herbal medicine resources.

2 Materials and Methods

2.1 Materials and Equipment

Polygonatum sibiricum was purchased from Jiuhua Mountain,China; Citric Acid and $CaCl_2$ were purchased from Chengdu Kelong Chemical Reagent Factory (Chengdu, China); Low-methoxy Pectin and Xanthan Gum were purchased from Shandong Bufeng Fermentation Co., Ltd. (Shandong, China); Xylitol were purchased from Shandong Mifutang Food Co., Ltd. Company (Shandong, China) . All the materials were of food grade.

2.2 Experimental Methods

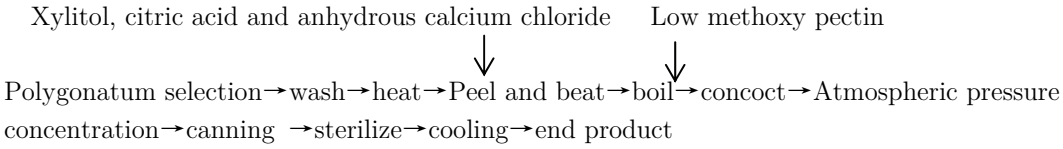

Figure 1. The process flow

2.2.1 Polygonatum jam preparation

Polygonatum [18] with moderate maturity, no damage and decay was used for jam. Put the Polygonatum into the rice cooker and cooked at atmospheric pressure for 8 h, and steaming was performed for 12 h [19], after removing, added water and mixed homogeneous. According to a definite ratio, citric acid, xylitol and $CaCl_2$ were added, and the mixing was continued during the addition and recorded Concentration time. Then pour the dissolved low-methoxy pectin into the puree and stirred for a while. After thoroughly cleaning the glass bottle and cap with water, sterilize with water vapor at a temperature of 100 ℃ for 10 min. After the jam was out of the pan, quickly filled the can and tightened the cap. The filling time of each pot of jam should not exceed 30 minutes, and the temperature of the jam should not be lower than 80 ℃ ~ 90 ℃. The low-sugar Polygonatum jam was sterilized at 95 ℃ ~ 100 ℃ for 30 min. After being taken out, it was allowed to cool at room temperature for 3 h, and stored at low temperature.

2.2.2 Single factor experiment

Four main factors affecting the quality of low-sugar Polygonatum jam were selected: xylitol, citric acid, $CaCl_2$, and low-methoxy pectin. The sensory score was used as the evaluation standard to determine the optimal dosage of the four factors [20]. The addition amount of fixed low-methoxy pectin, $CaCl_2$ and citric acid was 1%, 0.5%, and 0.06%. The effect on the sensory score and texture characteristics of low-sugar Polygonatum jam was determined with the xylitol (3, 6, 9, 12, and 15%, respectively) added [21].

The amount of xylitol, low-methoxy pectin and $CaCl_2$ added were 9%, 1%, and 0.5% respectively. The sensory scores and texture characteristics of low-sugar Polygonatum jam were affected with the addition of citric acid (0.03, 0.06, 0.09, 0.12, and 0.15%).

The added amount of xylitol, low-methoxy pectin and citric acid were 9%, 1%, and 0.06% respectively. When the amount of $CaCl_2$ added was 0.25, 0.50, 0.75, 1.00, and 1.25%, effect on sensory scores and texture characteristics of low-sugar Polygonatum jam.

The addition amount of fixed xylitol, $CaCl_2$ and citric acid were 9%, 0.5% and 0.06% respectively. The

effect of sensory score and texture characteristics of low-sugar Polygonatum jam with low-methoxy pectin addition (0.25, 0.50, 0.75, 1.00 and 1.25%) was evaluated.

2.2.3 Box-Benhnken center combination experiment design

Response surface methodology was used for the optimization of variables in the present study. A central composite design (CCRD) was used to study the effect of four independent variables at three levels on the response pattern and to determine the optimum combination of variables. The independent variables optimized were A (xylitol addition), B (citric acid addition), C ($CaCl_2$ addition), D (low-methoxy pectin addition) for dependent response Y (sensory score). The experimental factors and the horizontal coding were given in Table 1.

Table 1. Factor level and coding of Box-Behnken center combination experiment design

Factor	Coding level		
	-1	0	1
A xylitol addition (%)	6	9	12
B citric acid addition (%)	0.03	0.06	0.09
C $CaCl_2$ addition (%)	0.25	0.50	0.75
D low-methoxy pectin addition (%)	0.75	0.10	1.25

2.2.4 Sensory evaluation

Sensory evaluation table was prepared by standard, which combined with texture and flavor of low-sugar Polygonatum jam with slight modifications. Sensory properties of jam were evaluated by a panel of 20 semi-trained members. Panelists were formed for descriptive analysis for sensory evaluation of jam and then performed sensory score on the product, the percentage rating scored according to the scoring standard. Overall acceptability of jam was calculated from the average of all the parameters [22]. The sensory evaluation table was given in Table 2.

Table 2. Sensory evaluation standards of low-sugar Polygonatum jam

Rating item	Grading	Score
Organizational status (30 points)	Good gelatinity, no sugar, water precipitation, uniform and non-dispersive	20~30
	Good gelatinity, a small amount of sugar and water are precipitated, basically uniform, slightly dispersed	10~19
	General gelatinity, more precipitation than polysaccharides, water, uneven, scattered	1~9
Taste (30 points)	Moderate sweet and sour, pure and delicate taste, good toughness	20~30
	Slightly acidic or sweet, the taste is purer and finer, and the toughness is good.	10~19
	The ratio of sweet and sour is uncoordinated, the taste is rough, and the toughness is generally	1~9
Color (15 marks)	Light Polygonatum, shiny, no browning	10~15
	Light Polygonatum, brighter color	6~9
	Dark color, browning is serious	1~5
Aroma (15 marks)	Rich in Polygonatum	10~15
	Polygonatum is more intense	6~9
	Polygonatum is not obvious	1~5
Spreadability (10 points)	Easy to apply, even and smooth coating	8~10
	Easy to apply, even coating, not smooth	4~7
	Easier to apply, but the coating is incoherent	1~3

2.2.5 Jam texture

Texture Analyzer was used to measure the texture of the low-sugar Polygonatum jam via using probe P 0.5 rig, each sample was experimented 3 times. The textural studies were conducted at descent speed of 1.0

mm/s, test speed of 1.0 mm/s. Hardness, spreadability, cohesion, viscosity and other indicators can be obtained according to the texture chart.

2.2.6 Data analysis

The data were sorted by using Microsoft Excel 2007 software, and obtained from experiments was analyzed for analysis of variance (ANOVA) and regression models using Stat-Ease software (Design-Expert.8.0.6). A second-order polynomial was fitted to the data to obtain regression equations. The terms in the regression equations were examined for statistical significance. The significance of the models was analyzed using model analysis and coefficient of determination (R2) value, lack of fit F-value and model F-value. Response surface graphs were generated with the help of commercial statistical package. The response surface graphs obtained from experimental data showed the effect of variation in independent variables on the responses.

3 Results and Analysis

3.1 Single Factor Experiment Results and Analysis

3.1.1 Effect of xylitol addition on sensory score

Xylitol was used to increase the sweetness of the Polygonatum jam, and the amount added during the experiment was 3, 6, 9, 12, and 15% respectively. The experimental results are displayed in the table and comparing products by sensory evaluation and the texture analysis can be obtained: when the xylitol content was 3%, the product taste was poor, and the product was not easy to apply. When the amount of xylitol added was in the range of 6% to 9%, the sweetness and sourness of the Polygonatum jam were suitable, and the spreadability was good. As the amount of xylitol increased, the application performance of the Polygonatum jam increased. Due to the caramelization process of the sugar, the color of the prepared Polygonatum jam was deepened, the flavor of the Polygonatum jam was increased, the viscosity was increased, the good tissue morphology [23] was maintained, and the xylitol was excessive and the viscosity was too high. So, according to the comprehensive analysis, the content of xylitol was determined as 6% ~ 9%. Probably because the sugar content was 3%, the sugar concentration in the system was low, it cannot be tightly combined with water, the water was analyzed, the spreadability was poor, and the quality was degraded. When the sugar content of the system is 15%, the sugar concentration is too high, and the Polygonatum jam is dehydrated, so that the sample is electrically neutralized, a gel can be formed, the viscosity of the system is increased, and the spreadability is lowered.

Table 3. Effect of xylitol addition on quality of Polygonatum jam

Xylitol addition / %	Hardness / g	Spreadability / $g \cdot s^{-1}$	Cohesion / g	Viscosity / $Pa \cdot s^{-1}$	Sensory score/ fraction
3	13.80 ± 0.21^{b}	261.40 ± 60.64^{b}	5.27 ± 0.12^{e}	4.79 ± 0.05^{e}	61.33 ± 1.33^{d}
6	12.00 ± 0.49^{c}	206.93 ± 38.80^{c}	6.10 ± 0.09^{d}	7.76 ± 0.10^{d}	75.33 ± 12.33^{b}
9	10.77 ± 0.30^{d}	189.37 ± 11.02^{d}	6.73 ± 0.04^{c}	9.85 ± 0.01^{c}	83.67 ± 2.33^{a}
12	15.23 ± 0.30^{a}	260.47 ± 36.58^{b}	7.30 ± 0.13^{b}	13.12 ± 0.01^{b}	79.33 ± 6.33^{ab}
15	15.17 ± 0.82^{a}	274.23 ± 9.40^{a}	8.37 ± 0.06^{a}	17.64 ± 0.20^{a}	69.67 ± 17.33^{c}

Note: Based on 150g Polygonatum jam, all results are expressed as mean±standard deviation. Different lowercase letters in the same column indicate significant difference ($p < 0.05$), and the same letter indicates no significant difference ($p > 0.05$). Table 4, Table 5. Table 6 are the same.

3.1.2 Effect of citric acid addition on sensory score

Although the low-sugar Polygonatum jam has low-sugar content, it still has a sweet taste, while the Polygonatum contains insufficient acid and has to be adjusted by adding an appropriate amount of acidulant. Citric acid was used to improve the mouthfeel [24] and gel effect of the Polygonatum jam. The amount of citric acid added was 0.03, 0.06, 0.09, 0.12, and 0.15% respectively. Through sensory evaluation and the texture analysis, it can be seen that the taste of the Polygonatum jam was better, when the amount of citric acid added in the Polygonatum jam was in the range of 0.06% to 0.09%. In the meantime,

the taste was biased when the amount of citric acid added was in the range of 0.12% to 0.15%. As the content of citric acid increases, it was easy to apply. This was due to the H^+ increase, which was beneficial to the combination of thickener and sugar solution. H^+ also could reduce the repulsive force between chains and form a stable and orderly network structure. The result indicated that the performance of the Polygonatum was decrease with the jam addition. However, the excessive citric acid content resulted in a slight infiltration of water. The gel exhibited the elastic and fragile. Meantime, the gel fragmentation strength was lower, which might due to the high acidity of pectin. Some of the free fusions, which can be chelated with calcium, bind to hydrogen, which hinders the formation of calcium bridge. Therefore, the optimal addition of citric acid was 0.06%.

Table 4. Effect of citric acid addition on quality of Polygonatum jam

Citric acid addition amount/ %	Hardness / g	Spreadability / g · s $^{-1}$	Cohesion / g	Viscosity / Pa · s $^{-1}$	Sensory score/ fraction
0.03	13.80±0.28^{c}	286.93±115.04^{a}	6.33±0.26^{c}	17.44±13.79^{b}	77.00±13.00^{b}
0.06	12.23±0.12^{d}	242.03±128.56^{cd}	10.06±0.36^{a}	24.73±20.69^{a}	90.00±4.00^{a}
0.09	16.77±0.32^{a}	224.53±506.90^{d}	7.7±0.04^{b}	24.20±1.63^{a}	79.33±9.33^{b}
0.12	14.53±1.00^{bc}	261.73±12.41^{bc}	6.3±0.21^{c}	12.22±4.07^{c}	74.67±2.33^{b}
0.15	15.47±1.52^{ab}	268.17±62.74^{ab}	5.33±0.04^{d}	7.21±0.43^{c}	63.33±2.33^{c}

3.1.3 Effect of the addition of $CaCl_2$ on sensory score

The calcium ion in $CaCl_2$ can react with low-methoxy pectin to constitute a gel, which can improve the viscosity and gel effect of the jam. In this experiment, the amount of $CaCl_2$ added was 0.25. 0.50, 0.75, 1.00, 1.25%, respectively. The sensory evaluation and the texture analysis exhibited that the taste and gel effect of the Polygonatum jam was better with the amount of $CaCl_2$ (0.50% to 0.75%) added in the Polygonatum jam. In our research, when the concentration of $CaCl_2$ was low, the gel was not formed or the gel formation was extremely unstable. With the amount of $CaCl_2$ increased, the gelatin gel was soft. However, the hardness of the sample decreased with the excessive $CaCl_2$ addition. In addition, the cohesive force increases the increase of the concentration of $CaCl_2$, and reached the maximum when the addition amount was 0.50%. After that, the gel crushing strength decreases inversely with the increase of the concentration, and finally the water seepage was pre-gel phenomenon, and the texture characteristics greatly destroyed. Therefore, optimum addition amount of $CaCl_2$ was determined to be 0.5%.

Table 5. Effect of $CaCl_2$ addition on quality of Polygonatum jam

$CaCl_2$ addition amount/%	Hardness / g	Spreadability / g · s -1	Cohesion/ g	Viscosity / Pa · s $^{-1}$	Sensory score/ fraction
0.25	13.80±0.13^{ab}	276.10±82.93^{ab}	7.10±0.04^{b}	19.01±0.05^{b}	69.67±25.33^{cd}
0.50	14.93±0.05^{a}	240.53±10.29^{c}	9.07±0.26^{a}	24.48±0.45^{a}	88.67±9.33^{a}
0.75	13.90±0.16^{ab}	266.27±124.56^{b}	6.40±0.19^{b}	14.61±0.80^{c}	80.66±4.33^{b}
1.00	12.47±0.16^{bc}	261.93±40.34^{b}	6.20±0.21^{b}	11.93±0.27^{c}	74.00±13.00^{bc}
1.25	11.90±3.16^{c}	285.07±105.44^{a}	6.50±0.63^{b}	14.95±24.69^{bc}	63.67±16.33^{d}

3.1.4 Effect of low-methoxy pectin addition on sensory score

In a limited solvent, as the concentration of pectin increases, the number of pectin molecules per was increased, and the gap between the pectin gradually decrease, so that the gel texture formed becomes hard and the crushing strength enhancement. At the same time, the rise of the carboxyl group per unit volume increased the probability of binding to calcium ions which was due to the the concentration of the pectin increased, and resulted the better gel textured characteristics in some extent. However, the gel tends to appear as the concentration increases. The texture was hard and brittle is one of the signs of reduced elasticity, which could clearly reflect in the texture measurement [25]. It can be seen that the concentration of pectin is one of the crucial factors affecting the texture of pectin gel. The low-methoxy pectin addition amount was selected to be five levels of 0.25, 0.50, 0.75, 1.00, and 1.25%. As shown in Table 6, the sensory score of Polygonatum jam was the highest when the amount of the low-methoxy pectin was 1.00%, and the

gelatin effect of the Polygonatum jam was good and the taste was pure. Continue to add low-methoxy pectin, the sensory score of the jam decreased with the increase of low-methoxy pectin, and the taste was worse. Therefore, the optimum addition amount of the low-methoxy pectin was determined to be 1.00%.

Table 6. Effect of low-methoxy pectin addition on quality of Polygonatum jam

Low methoxy pectin addition / %	Hardness / g	Spreadability / g · s^{-1}	Cohesion / g	Viscosity / Pa · s^{-1}	Sensory score/ fraction
0.25	9.87±0.49^{d}	318.20±119.91^{a}	11.67±0.65^{a}	15.37±8.93^{e}	60.67±4.33^{d}
0.50	11.77±0.49^{c}	277.90±136.09^{b}	10.03±0.30^{b}	19.58±0.53^{d}	68.00±7.00^{c}
0.75	14.67±3.52^{b}	260.03±128.10^{b}	8.97±0.06^{b}	24.14±1.98^{c}	80.67±16.33^{b}
1.00	16.70±0.19^{a}	261.53±306.30^{b}	6.77±0.32^{c}	27.89±1.83^{b}	87.67±6.33^{a}
1.25	18.17±0.41^{a}	260.30±76.63^{b}	6.60±1.33^{c}	31.95±5.07^{a}	79.33±6.33^{b}

3.2 Response Surface Experiment Results Analysis

3.2.1 Response surface experiment design and results

Table 7. Box-Behnken Design and results of response surface experiments

Experimental coding	Factor coding level				Sensory score/ fraction
	A	B	C	D	
1	0	-1	1	0	83
2	1	1	0	0	79
3	1	0	-1	0	87
4	0	1	1	0	78
5	0	0	1	-1	82
6	0	0	-1	1	84
7	0	-1	0	-1	81
8	0	0	0	0	94
9	1	0	1	0	85
10	-1	0	0	-1	77
11	-1	1	0	0	80
12	0	1	0	1	78
13	0	1	-1	0	75
14	1	0	0	1	82
15	0	0	1	1	87
16	0	-1	0	1	84
17	-1	0	-1	0	81
18	1	-1	0	0	87
19	-1	0	0	1	83
20	0	1	0	-1	74
21	0	0	-1	-1	82
22	0	-1	-1	0	84
23	-1	-1	0	0	86
24	0	0	0	0	96
25	1	0	0	-1	86
26	0	0	0	0	93
27	-1	0	1	0	87
28	0	0	0	0	96
29	0	0	0	0	94

According to the results of the single factor experiment, the experimental protocol and results obtained by Design-Expert 8.0.6 software were shown in Table 7. Sensory score of low-sugar Polygonatum jam as

the response value, xylitol (A), citric acid (B), $CaCl_2$ (C) and low-methoxy pectin (D) was a four-factor and three-level experimental scheme for the independent variable.

3.2.2 Response surface variance analysis results

Using the Design Expert 8.0.6 software to perform the quadratic polynomial regression fitting on the experimental data of Table 3, the regression model is obtained: Y=94.60+1.00A-3.42B+0.75C+1.33D-0.50AB-2.00AC-2.50AD+1.00BC+0.25BD+0.75CD-4.47A2-8.34B2-5.09C2-6.97D2, the variance analysis was performed on the experimental results by Box-Benhnken response surface analysis. As shown in Table 8, the significance of the influence of each factor of the regression equation on the sensory score is determined by the F-value. If the probability P-value is small, it indicates that the corresponding factor has a higher degree of significance.

Table 8 demonstrates that the model has an F-value of 22.14 and P-value < 0.0001, indicating that the model is very significant, which reflect that the experiment is consistent with the experimental results at the experiment site. The F-value of the misfit is 1.97. The P-value is $0.2687 > 0.05$, which is not significant, indicating that the regression equation has a good fit in the regression space. The linear relationship between each factor and the response value is obvious. This model can be used to analyze and predict the sensory score of low-sugar Polygonatum jam.

When the P-value <0.05, the model factor is significant, so B, D, AC, AD, A2, B2, C2, D2 are significant. AC and AD are significant, indicating that the interaction of xylitol with $CaCl_2$, xylitol and low-methoxy pectin have an effect on the sensory score of low-sugar Polygonatum jam. From the F-value experiment, the order of influence of each factor on the sensory evaluation of low-sugar Polygonatum jam was: citric acid addition amount > low-methoxy pectin addition amount > xylitol addition amount > $CaCl_2$ addition amount.

Table 8. Results of ANOVA of response surface analysis

Factor	Sum of square	Degree of freedom	Mean square	F-value	P-value	Significant
A	12.00	1	12.00	3.94	0.0670	
B	140.08	1	140.08	46.02	< 0.0001	**
C	6.75	1	6.75	2.22	0.1586	
D	21.33	1	21.33	7.01	0.0191	*
AB	1.00	1	1.00	0.33	0.5756	
AC	16.00	1	16.00	5.26	0.0379	*
AD	25.00	1	25.00	8.21	0.0125	*
BC	4.00	1	4.00	1.31	0.2709	
BD	0.25	1	0.25	0.082	0.7786	
CD	2.25	1	2.25	0.14	0.4044	
A2	129.41	1	129.41	42.51	< 0.0001	**
B2	451.35	1	451.35	148.27	< 0.0001	**
C2	168.16	1	168.16	55.24	< 0.0001	**
D2	314.82	1	314.82	103.42	< 0.0001	**
Model	943.59	14	67.40	22.14	< 0.0001	**
Residual	42.62	14	3.04			
Degree of misfit	35.42	10	3.54	1.97	0.2687	
Pure error	7.20	4	1.80			
Sum	986.21	28				

Note: **significant at $P < 0.0001$; *significant at $P < 0.05$

3.2.3 Response surface analysis

The response surface graph is a three-dimensional surface graph composed of sensory score Y for each experimental factor. As shown in the surface map, the optimal parameters and the interaction between the various parameters can be found. The three-dimensional surface curve composed of xylitol addition amount (A), citric acid addition amount (B), $CaCl_2$ addition amount (C) and low-methoxy pectin addition amount (D) is shown in Fig. 2.

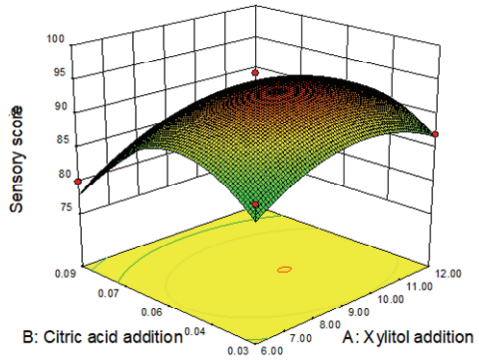

Figure a

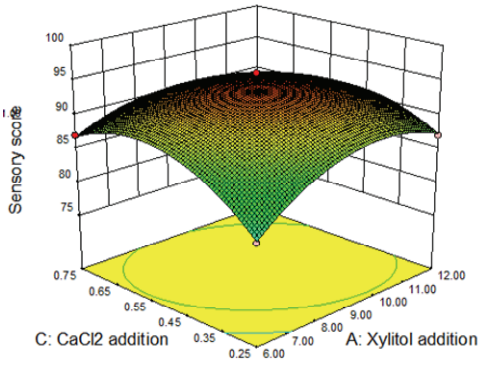

Figure b

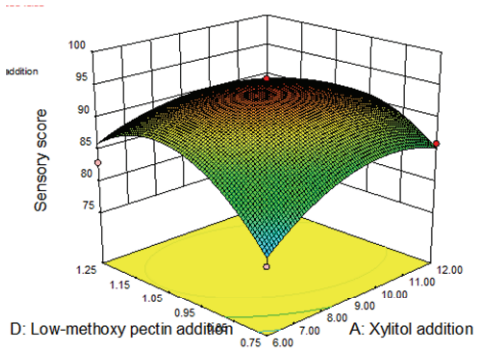

Figure c

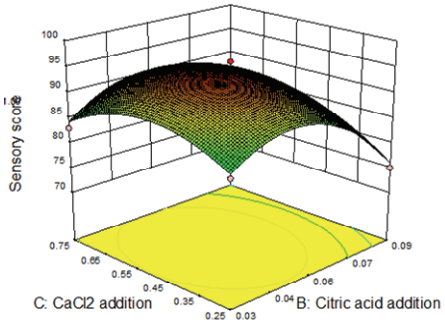

Figure d

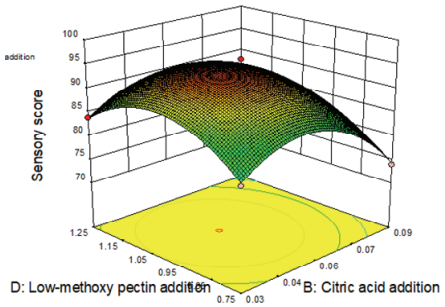

Figure e

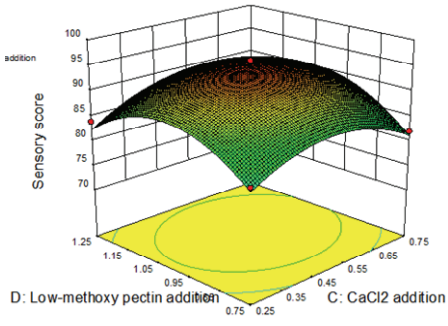

Figure f

Figure 2. Response surface and contour plots for the effect on sensory score

According to the 3D surface map shown in Figure 2, the influence of various factors on the sensory score and the interaction between the various factors can be analyzed. It can be seen from the figure that when xylitol, citric acid, $CaCl_2$, low-methoxy pectin. When any two factors between methoxy pectin as zero level, the sensory score increases with the increase of the other two factors. After reaching a certain value, the surface slowly decreases, the curves of graphs b and c are steeper than the other two. The steep surface indicates that the interaction between xylitol and $CaCl_2$, xylitol and low-methoxy pectin are more obvious, which consistent with the analysis of variance.

It can be seen from Fig. 2 that the response surface pattern is curved surface with convex surface and a downward opening, indicating that there is an extreme value of the sensory score Y, which is the highest point of the response surface, and the optimal action point of each experimental factor is located at the experimental design value. Within the range, the sensory score increased first and then decreased with the addition of citric acid, $CaCl_2$, low-methoxy pectin and xylitol increased. It clearly that proper xylitol and low-methoxy pectin can improve the taste of the low-sugar Polygonatum jam. The contour map can determine the significance of the interaction. The contour map tends to ellipse, and the interaction is

significant. As shown in Figure 2 (b, c), the contour maps of AC and AD interactions are elliptical, indicating the significant interaction between AC and AD. The contour maps of AB, BC, BD, and CD tend to be circular, indicating that the interaction is not significant, as shown in Figure 2 (a, d, e, f). The degree of density of the contour line can determine the influence of various factors on the sensory score. The denser the contour line, the greater the influence. It is clearly from the Figure 2, the citric acid added (B) has the biggest effect on the sensory quality of low-sugar Polygonatum jam compared with the xylitol added (A), $CaCl_2$ (C) and the low-methoxy pectin added (D). Meantime, the low-methoxy pectin (D) has the biggest effect of sensory quality compared to the xylitol (A), $CaCl_2$ (C). The amount of xylitol added (A) has a lower effect on the sensory quality of low-Polygonatum Polygonatum jam than $CaCl_2$. These results are consistent with the results of the analysis of variance.

3.2.4 Model verifications

Numerical optimization of processing variables was done by using Design-Expert (8.0.6) software. Optimum values for processing variables were obtained after assigning certain constraints processing variables. The optimum values of processing variable and responses exhibited as follows: xylitol 9.28%, citric acid 0.05%, $CaCl_2$ 0.51%, and low-methoxy pectin 1.02%. Confirmative test for verification of model was carried out using optimum levels of independent variables. And the actual values obtained at optimum conditions of processing variables were 95.1. In order to verify the reliability of the response surface results, the confirmatory experiment of the low-sugar Polygonatum jam was carried out according to the optimal conditions obtained by the experiment. After three parallel experiments, the sensory score of the low-sugar Polygonatum jam were 95, 96, and 96. The average sensory score was 95.67, and the error from the theoretical value was within 1%. Thus, the experimental results and the regression models were validated through the confirmative test.

3.3 Physical and Chemical Indicators

According to the measurement method, soluble solids, total acid content, total sugar content and viscosity of the low-Polygonatum Polygonatum jam were measured and shown in Table 9.

Table 9. The physical and chemical indicators of low-sugar Polygonatum jam

Project	The measurement results
Soluble solids (refractometer at 20 ℃) / (%)	34.5
Total acid / (g / 100g)	0.2344
Total sugar / (g / 100g)	37.82
Viscosity / (Pa / s)	35

3.4 Microbial Indicators

The total number of bacteria < 20 / g; the number of coliforms < 30 / 100 g; pathogenic bacteria cannot be detected.

4 Conclusion

Optimization of processing variables for preparation of low-sugar Polygonatum jam was effectively done using response surface methodology. The optimum conditions for desired values of responses such as sensory score were obtained by the regression analysis for modeling of processing variables. Model validation was done by analyzing various significant statistical aids such as F-value. All of these terms revealed the statistical adequacy of the model. It is concluded that the order of influence of various factors on the sensory evaluation of low-sugar Polygonatum jam was as follows: the amount of citric acid added > the amount of low-methoxy pectin added > the amount of xylitol added > the amount of $CaCl_2$ added. Optimum values for the processing parameters were obtained from numerical optimization technique, which also satisfied the criterion of constraints of the responses. The predicted and experimental values were in accord with each other. The ideal parameters to product low-sugar Polygonatum jam were as follows: xylitol 9.28%, citric acid 0.05%, $CaCl_2$ 0.51%, and low-methoxy pectin 1.02%.

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