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The Optimization of Jelly with Blueberry Juice using Response Surface Methodology

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반응표면분석법을 이용한 블루베리 즙 첨가 젤리의 최적화

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국문요약

이 연구는 블루베리 즙을 첨가하여 젤리의 제조조건을 최적화하고자 하였다. 16개의 블루베리 즙을 이용한 젤 시료는 Design Expert 프로그램을 이용하여 제조하였으며, 최적화를 위해 블루베리 즙(100～200 g), 설탕(40～160 g), 젤라틴(8～20 g)의 양을 독립변수로, 텍스처, pH, 관능평가 항목을 종속변수로 각각 선정하였다. 반응표면 분석법을 사용하기 위한 실험설계로 중심합성계획을 이용하였다. 각 항목별 최적조건은 Canonical 모형의 수치 최적화(numerical optimization)과 모형적 최적화(graphical optimization)를 통하여 선정하였으며, 그 중 가장 높은 desirability를 갖는 최적점을 선택하여 지점 예측(point prediction)을 통해 도출한 결과, 각 독립변수의 예측된 블루베리 즙을 첨가한 젤리의 최적값은 블루베리 주스 133.63 g, 설탕 160.0 g, 젤라틴은 12.78 g이었다.

Key words: blueberry juice, jelly, design expert, RSM

INTRODUCTION

A number of sample population based studies have demonstrated the beneficial effects of fruit and vegetable intake on indices of health in humans (Devareddy et al. 2008).

Antioxidants and phytochemicals in fruits and vegetables reduce the risk of several chronic and degenerative diseases (Murphy et al. 2009).

Blueberries contain a group of phytochemicals including gallic acid p-hydroxybenzoic acid, chlorogenic, p-coumaric, caffeic, ferulic, ellagic acids, anthocyanins, catechin, and quercetin (Devareddy et al. 2008). Blueberries prevent several diseases in rat model according to previous studies. Blueberry supplementation may protect against neurodegeneration and cognitive impairment mediated by excitotoxicity and oxidative stress (Duffy et al. 2007). Blueberries can prevent bone loss caused by ovarian hormone deficiency (Devareddy et al. 2008). Also, consumption of blueberry polyphenols reduces exercise-induced oxidative stress compared to vitamin C and may be beneficial for athletes exercising in hot environments (McAnulty et al. 2004).

Jelly is a widely consumed dessert, appreciated for their texture and ease of cooking. As one of western desserts, jelly is a gel state food by containing about 20% of water and various textures could be assigned by using different gelling agents and manufacturing of various jelly products can be expected from different manufacturing process. Therefore, the use of natural ingredients, exhibiting functional properties and providing specific health benefits, is a very attractive way to design new food products

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(Gouveia et al. 2007).

Cooking wild blueberries does not diminish antioxidant capacity and dietitians can recommend consumption of all types of wild blueberries for disease prevention (Murphy et al. 2007).

RSM has been an effective statistical method for optimizing experimental conditions and investigation of critical processes by reducing the number of experimental trials (Myers & Montgomery 2002).

Therefore, in this study, to develop jelly using blueberry juice, according to the Central Composition Design, blueberry was produced by varying the content of blueberry juice (X_1), sugar (X_2) and gelatin (X_3) at 5 levels. Applying the Response Surface Methodology, physical properties and sensory evaluation experiments results were analyzed. The optimization of blueberry jelly manufacturing condition was carried out and studies on the analysis of composition were performed.

MATERIAL AND METHODS

1. Material

The blueberry juice used in this experiment was obtained from Aysu (Cultivated blueberries, U.S.A.). Also, sugar (CJ, Korea), gelatin (Knox, Kraft Foods North America, U.S.A.) and citric acid (Shinwon industrial Co., Ltd, Korea) were used. Purified water was used.

2. Experimental Design

The Design Expert 7 Program was used for the research plans, data analysis and optimization analysis on blueberry jelly. As independent variables, the three factors chosen were blueberry juice, sugar and gelatin, and for dependent variables, color values (L, a, b), textural evaluation (hardness, adhesiveness, springiness, chewiness, gumminess and cohesiveness) and sensory evaluation (color, flavor, clarity, taste, hardness, springiness and overall quality) were chosen. Through preexaminations the maximum and minimum range of blueberry juice, sugar and gelatin were determined to be 10～200 g, 40～160 g, 8～20 g respectively. Blueberry juice and water made 400 g and citric acid was limited to 2 g. The experimental points of Central Composite consist of the most central point, $\pm\alpha$ point(axial point) and ±1 level point (factorial point), and between these experimental points, there exist an iterative point for the selection of a model and the verification of fitness lack. Accordingly, when each established scope was inputted, forming 16 experimental points, 2 iterative points were selected through the establishment of replication (Seo et al. 2006). The mixture ratio the jelly to blueberry juice are as seen in Table 1.

Table 1. Experimental design for blueberry jelly

Sample No.[1]	Variable level[2]		
	X_1	X_2	X_3
1	10	40	8
2	200	40	8
3	10	160	8
4	200	160	8
5	10	40	20
6	200	40	20
7	10	160	20
8	200	160	20
9	10	100	14
10	200	100	14
11	105	40	14
12	105	160	14
13	105	100	8
14	105	100	20
15	105	100	14
16	105	100	14

[1] Sample No: The number of experimental conditions by central composite design, [2] X_1: blueberry, X_2: sugar, X_3: gelatin.

3. Preparation of Jelly

The standard formulation for product treatment consisted of blueberry juice, water, sugar, gelatin and citric acid. Blueberry juice and water were mixed. The gelatin was used to dissolve half of mixed blueberry juice and water for 5 min. The remaining half of mixed blueberry juice and water was added and the mixture was boiled to 70℃. Afterward, sugar was added and the mixture was boiled to 100℃. Lastly, citric acid was added after taking the product off the fire.

4. Color Measurement

The color values (L, a and b value) of the blueberry jelly were measured using a colorimeter (Colormeter CR-200, Minolta Co., Japan). The colorimeter was calibrated using a standard white plate with L, a and b values of 97.26, －0.07 and +1.86, respectively. Three measurements were made for each treatment.

5. pH Value Measurement

The pH value of the blueberry jelly was measured using a pH meter (340, Mettler Toledo, UK). Three measurements were made for each treatment.

6. Texture Analysis

The texture of blueberry jelly was measured using a texture analyzer (Model TAXT express, Stable Micro system Ltd., UK). TPA parameters (hardness, adhesiveness, springiness, chewiness, gumminess, cohesiveness) were calculated. The operating conditions of the texture analyzer is shown in Table 2.

7. Sensory Evaluation

The panel consisted of 16 students at Sookmyung Women's University. The panelists were asked to score the color, flavor, clarity, taste, hardness, springiness and overall quality of the blueberry jelly with points ranging from 1 (dislike extremely) to 7 (like extremely). The blueberry jelly prepared for each test sample was recorded with a random 4 digit number. Water was provided for mouth-rinsing between consecutive evaluations.

8. Optimization

Through numerical optimization of a Canonical Model and graphical optimization, the optimal quantities of blueberry juice, sugar and gelatin was chosen, by which the optimal point was selected using the point found through point prediction. For numerical optimization, the goal area was set with the highest point of the sensory test from the coefficients of the standard canonical model.

Through numerical optimization, the optimal point showing the highest desirability was selected after acquiring the desirability through the following formula.

$$D = (d_1 \times d_2 \times \cdots \times d_n)^{\frac{1}{n}} = \left(\prod_{i-1}^{n} d_i\right)^{\frac{1}{n}}$$

Table 2. Operating conditions for texture analyzer

Instrument	Texture analyzer
Type	Compression test (Texture Profile Analysis test)
Adaptor type	3
Pre-test speed	3 ㎜/sec
Test speed	3 ㎜/sec
Post test speed	3 ㎜/sec
Distance	15 ㎜
Trigger force	35 g

Here, D is the overall desirability, d is each desirability and n is the number of responses (9, 10).

9. Statistical Analysis

Statistical analysis of variance (ANOVA) and multiple regression were performed using the Design-Expert 7 program (Stat-Easy Co., Minneapolis) to fit the equation. The results included the significance of the model and of each of its terms., the estimated model coefficients, the coefficient of determination, and the lack of fit test.

RESULT AND DISCUSSION

1. Physicochemical Characteristics

According to Central Composite Design which was used to optimize the manufacturing conditions for blueberry jellies, the results of physicochemical measurements from 16 conditions with 3 variables are as follows.

1) Color Values and pH

The color value and pH results from 16 conditions with 3 variables are as in Table 3. The model equations and the coefficients of determination of the model equation are given in Table 4.

The values of L, a and b were in the ranges of 20.71～27.23, 0.75～9.37 and −0.58～4.85, respectively. The evaluation of L, a and b show that increased blueberry juice significantly decreased L (p<0.001), a (p<0.001) and b (p<0.001). It was similar to a previous study that Lightness, redness and yellowness of jelly decreased with increasing black garlic content (Lee et al. 2010).

Shown in Figure 1 is the response surface for the effect of blueberry juice, sugar and gelatin on color values blueberry jelly.

The pH values of blueberry jelly were in the range of 2.90～3.37 which is acidic, 7 being neutral.

2) Textural Characteristics

The results of texture parameters are shown in Table 3. The model equations and the coefficients of determination of the model equation are as in Table 4. The addition of gelatin had a positive effect on the hardness, adhesiveness, springiness, chewiness, gumminess, cohesiveness obtained from the texture analyzer. Increased gelatin significantly increased the texture parameters (p<0.001). It was similar to a previous study that

Table 3. Experimental combinations and data under various conditions of blueberry, sugar, gelatin and their responses

Sample No.[1)]	Variable level[2)]			Responses[3)]									
	X_1	X_2	X_3	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9	Y_{10}
1	10	40	8	23.68	9.37	3.40	2.93	2,467.27	−33.90	1.01	591.79	532.96	0.23
2	200	40	8	21.94	0.75	−0.58	2.91	2,684.23	−59.13	0.88	450.60	503.29	0.18
3	10	160	8	27.23	8.05	2.19	2.97	3,011.47	−174.07	0.54	218.98	407.55	0.13
4	200	160	8	23.56	0.91	−0.64	2.92	3,933.40	−211.67	0.50	338.24	677.10	0.17
5	10	40	20	24.86	6.15	3.16	3.35	3,230.27	−4.70	1.55	4,675.38	3,022.97	0.94
6	200	40	20	20.71	0.95	0.54	3.14	3,756.83	−16.87	1.38	4,700.85	3,448.79	0.92
7	10	160	20	25.46	7.83	4.85	3.37	4,567.13	−6.33	1.51	6,254.63	4,143.71	0.91
8	200	160	20	22.14	1.09	−0.37	3.16	4,657.40	−12.63	1.44	5,928.68	4,140.52	0.89
9	10	100	14	25.41	8.66	3.82	3.15	2,293.93	−22.97	1.37	1,987.35	1,295.32	0.51
10	200	100	14	20.63	1.00	0.41	3.03	3,437.87	−4.70	1.52	4,394.64	2,889.42	0.84
11	105	40	14	21.35	1.96	−0.46	3.08	2,596.47	−0.37	1.63	3,311.75	2,028.43	0.77
12	105	160	14	22.82	2.47	0.28	3.08	4,002.23	−14.70	1.26	3,917.83	3,001.44	0.74
13	105	100	8	22.44	2.09	0.38	2.90	2,386.53	−126.37	0.46	157.58	339.95	0.14
14	105	100	20	20.66	2.50	−0.24	3.23	3,551.23	−8.63	1.43	4,346.96	2,944.68	0.83
15	105	100	14	22.82	2.06	−0.44	3.07	3,207.67	−2.80	1.51	3,739.75	2,394.57	0.74
16	105	100	14	22.83	2.11	−0.41	3.08	3,322.47	−3.40	1.53	3,955.78	2,575.81	0.78

1) Sample No.: The number of experimental conditions by central composite design,
2) X_1: blueberry (10～200 g), X_2: sugar (40～160 g), X_3: gelatin (8～20 g),
3) Y_1: L (white + 100 ↔ 0 black), Y_2: a (red + 60 ↔ −60 green), Y_3: b (yellow + 60 ↔ −60 blue), Y_4: pH, Y_5: hardness, Y_6: adhesiveness, Y_7: springiness, Y_8: chewiness, Y_9: gumminess, Y_{10}: cohesiveness.

Table 4. Analysis of the predicted model equation for the color values and pH of blueberry jelly

Responses[1)]	Model	R-squared	*F*-value	*P*-value Prob>F[2)]	Equation of on terms of pseudo component[3)]
Y_1	Linear	0.7455	11.72	0.0007***	$23.03-1.77X_1+0.87X_2-0.50X_3$
Y_2	Quadratic	0.9859	46.55	<0.0001***	$2.30-3.54X_1+0.12X_2-0.27X_3-7.50E-003X_1X_2+0.48X_1X_3+0.37X_2X_3+2.42X_1^2-0.19X_2^2-0.11X_3^2$
Y_3	Quadratic	0.9291	8.74	0.0079**	$-0.043-1.80X_1+0.025X_2+0.32X_3-0.18X_1X_2-0.13X_1X_3+0.26X_2X_3+1.98X_1^2-0.24X_2^2-0.079X_3^2$
Y_4	Quadratic	0.9987	514.99	<0.0001***	$0.37-0.061X_1+9.000E-003X_2+0.16X_3-3.750E-003X_1X_2-0.044X_1X_3-1.250E-003X_2X_3+0.019X_1^2+8.621E-003X_2^2-6.379E-003X_3^2$
Y_1	Linear	0.8090	16.94	0.0001***	$3319.15+289.97X_1+543.66X_2+528.00X_3$
Y_2	Quadratic	0.9682	20.28	0.0008***	$-8.00-6.30X_1-30.44X_2+55.60X_3-0.81X_1X_2+5.55X_1X_3+36.91X_2X_3-3.39X_1^2+2.91X_2^2-57.05X_3^2$
Y_3	Quadratic	0.9664	19.16	0.0009***	$1.44-0.026X_1-0.12X_2+0.39X_3+0.024X_1X_2-8.750E-003X_1X_3+0.11X_2X_3+0.052X_1^2+0.052X_2^2-0.45X_3^2$
Y_4	Linear	0.8872	31.45	<0.0001**	$+3060.67+208.49X_1+292.80X_2+2414.94X_3$
Y_5	Linear	0.9060	38.55	<0.0001***	$2146.66+225.66X_1+238.39X_2+1523.98X_3$
Y_6	Quadratic	0.9638	17.75	0.0012**	$0.72+0.028X_1-0.020X_2+0.36X_3+0.011X_1X_2-3.750E-003X_1X_3+6.250E-003X_2X_3-0.022X_1^2+0.058X_2^2-0.21X_3^2$

1) Y_1: L (white + 100 ↔ 0 black), Y_2: a (red + 60 ↔ −60 green), Y_3: b (yellow + 60 ↔ −60 blue), Y_4: pH, Y_5: hardness, Y_6: adhesiveness, Y_7: springiness, Y_8: chewiness, Y_9: gumminess, Y_{10}: cohesiveness, 2) *p<0.05, **p<0.01, ***p<0.001,
3) X_1: blueberry (g), X_2: sugar (g), X_3: gelatin (g).

hardness and smoothness of milk jelly estimated by a subjective method were influenced by the content of gellan gum (Moritaka et al. 1998).

2. Sensory Evaluation

The values of color, flavor, clarity, taste, hardness, springiness and overall quality were in the ranges of 2.17～5.83, 2.83～5.17, 2.83～6.00, 1.83～5.33, 2.33～6.00, 2.83～5.67, 2.50～5.33, respectively (Table 5). The model equations and coefficients of determination of the model equation are given in Table 6.

According to Table 6, the sensory evaluation results showed significant values in color ($p<0.05$), flavor ($p<0.001$), clarity ($p<0.01$), taste ($p<0.01$), hardness ($p<0.01$), springiness ($p<0.01$) and overall quality ($p<0.05$).

Regarding flavor, it was shown that as more blueberry juice was added, the more the preference in flavor increased. But, as more gelatin was added, the more the preference in flavor decreased. This is consistent with the well known fact that flavor release in harder gels is smaller than for softer gels (Moritaka et al. 1998).

Regarding taste, it was shown that the as more blueberry juice, sugar and gelatin was added, the more the preference in taste increased.

It was shown that the more was added gelatin, the more the preference in springiness decreased.

With regards to overall quality, it was shown that the more gelatin was added, the more the preference in overall quality decreased. It was similar to a previous study that jelly is influenced greatly by gelatin generally (Kim & Joo 2008; Park & Joo 2006).

Shown in Figure 1 is the response surface for the effect of blueberry juice, sugar and gelatin on sensory characteristics on blueberry jelly.

3. Optimization

The optimal amounts of blueberry juice, sugar and gelatin were selected through numerical optimization of a canonical model and through graphical optimization. All the significant items shown in the sensory evaluation were determined by their maxima, from which the response formula determined by the modeling acquired was utilized, and the numerical point was selected through numerical optimization (Figure 2) and graphical optimization (Figure 3). The optimal point with the highest desi-

Table 5. Experimental combinations and data under various conditions of blueberry, sugar, gelatin and their responses

Sample No.[1)]	Variable level[2)]			Responses[3)]						
	X_1	X_2	X_3	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7
1	10	40	8	4.67	3.17	5.17	3.33	4.67	4.17	4.17
2	200	40	8	5.17	5.17	4.67	5.00	6.00	5.67	5.17
3	10	160	8	4.50	4.00	5.17	4.33	4.33	4.00	3.67
4	200	160	8	4.67	5.17	4.00	5.00	5.00	4.67	4.83
5	10	40	20	2.17	2.83	2.83	1.83	2.33	2.83	2.50
6	200	40	20	3.17	4.67	3.00	3.83	2.67	3.50	3.33
7	10	160	20	3.50	3.00	3.83	3.17	3.33	4.00	3.33
8	200	160	20	4.33	4.83	4.50	4.83	4.00	4.00	4.50
9	10	100	14	4.00	3.33	4.33	4.17	5.00	4.50	4.00
10	200	100	14	3.83	5.17	3.33	4.67	5.00	5.17	4.33
11	105	40	14	5.50	4.50	5.33	4.17	5.00	5.00	4.17
12	105	160	14	5.83	5.00	6.00	5.33	5.33	5.17	5.33
13	105	100	8	5.33	4.67	5.67	5.33	4.33	3.83	4.50
14	105	100	20	5.67	4.67	5.50	4.00	3.17	3.17	4.67
15	105	100	14	5.33	4.17	5.33	5.17	5.17	5.17	5.33
16	105	100	14	5.50	4.67	5.17	4.67	5.50	5.67	5.00

1) Sample No: The number of experimental conditions by central composite design,

2) X_1: blueberry (10～200 g), X_2: sugar (40～160 g), X_3: gelatin (8～20 g),

3) Y_1: color, Y_2: flavor, Y_3: clarity, Y_4: taste, Y_5: hardness, Y_6: springiness, Y_7: overall quality.

Table 6. Analysis of the predicted model equation for the quality characteristics of blueberry jelly

Responses[1)]	Model	R-squared	F-value	P-value Prob>F[2)]	Equation of on terms of pseudo component[3)]
Y_1	Quadratic	0.9000	6.00	0.0205*	$5.48+0.23X_1+0.22X_2-0.55X_3-0.063X_1X_2+0.14X_1X_3+0.39X_2X_3-1.59X_1^2+0.16X_2^2-9.138E-003X_3^2$
Y_2	Linear	0.8453	21.85	<0.0001***	$4.31+0.87X_1+0.17X_2-0.22X_3$
Y_3	Quadratic	0.9343	9.48	0.0064**	$5.37-0.18X_1+0.25X_2-0.50X_3-0.021X_1X_2+0.31X_1X_3+0.40X_2X_3-1.60X_1^2+0.24X_2^2+0.16X_3^2$
Y_4	Quadratic	0.9490	12.40	0.0031**	$4.94+0.65X_1+0.45X_2-0.53X_3-0.17X_1X_2+0.17X_1X_3+0.17X_2X_3-0.53X_1^2-0.20X_2^2-0.29X_3^2$
Y_5	Quadratic	0.9518	13.18	0.0026**	$5.12+0.30X_1+0.13X_2-0.88X_3-0.041X_1X_2-0.12X_1X_3+0.46X_2X_3-5.517E\text{-}003X_1^2+0.16X_2^2-1.26X_3^2$
Y_6	Quadratic	0.9251	8.24	0.0092**	$5.00+0.35X_1+0.067X_2-0.48X_3-0.19X_1X_2-0.19X_1X_3+0.35X_2X_3+0.046X_1^2+0.30X_2^2-1.29X_3^2$
Y_7	Quadratic	0.8616	4.15	0.0486*	$4.95+0.45X_1+0.23X_2-0.40X_3+0.062X_1X_2-0.020X_1X_3+0.35X_2X_3-0.68X_1^2-0.097X_2^2-0.26X_3^2$

1) Y_1: color, Y_2: flavor, Y_3: clarity, Y_4: taste, Y_5: hardness, Y_6: springiness, Y_7: overall quality, 2) * p<0.05, ** p<0.01, *** p<0.001,
3) X_1: blueberry (g), X_2: sugar (g), X_3: gelatin (g).

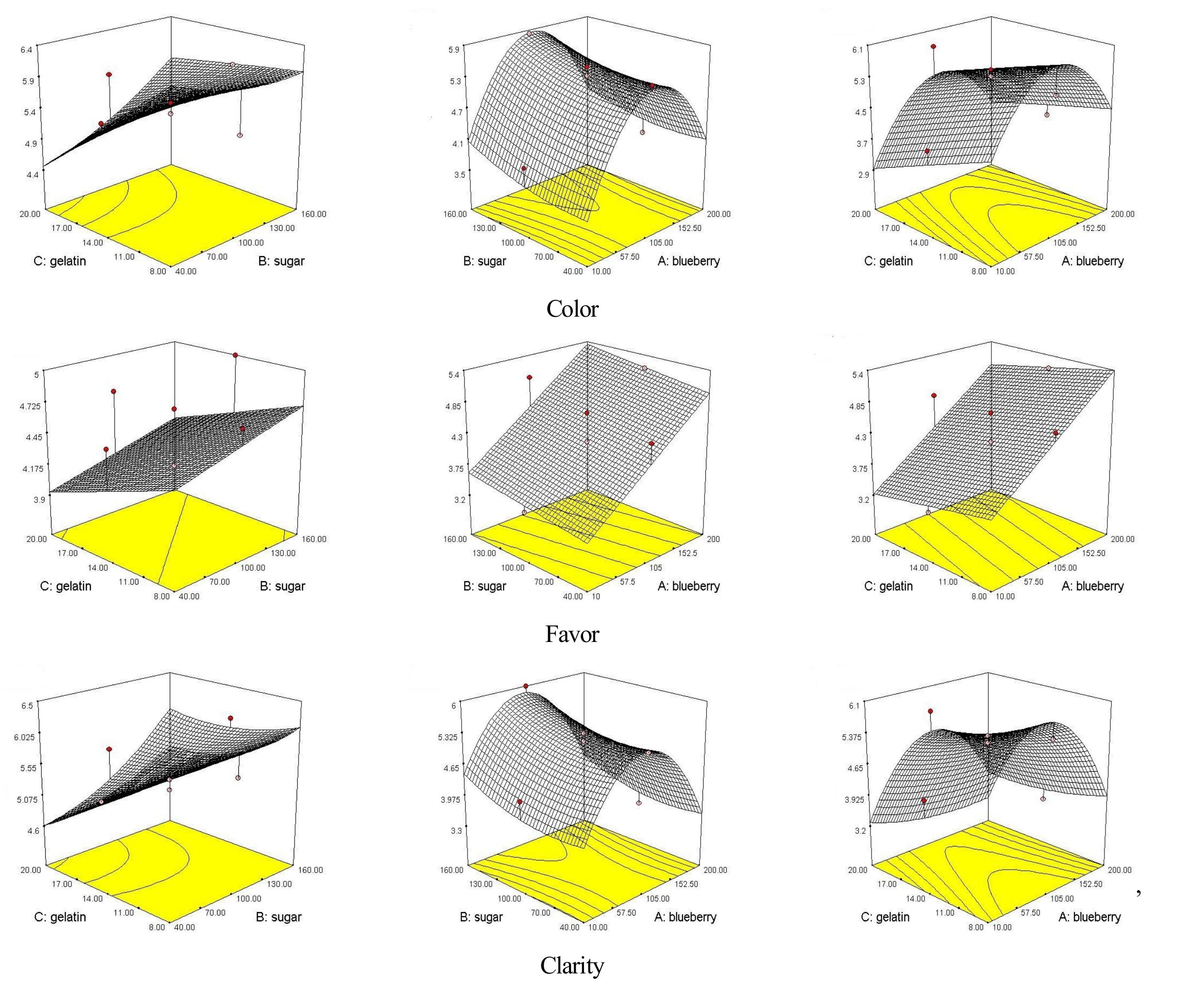


Fig. 1. Response surface for the effect of blueberry (A), sugar (B), gelatin (C) on the sensory characteristics of blueberry jelly.

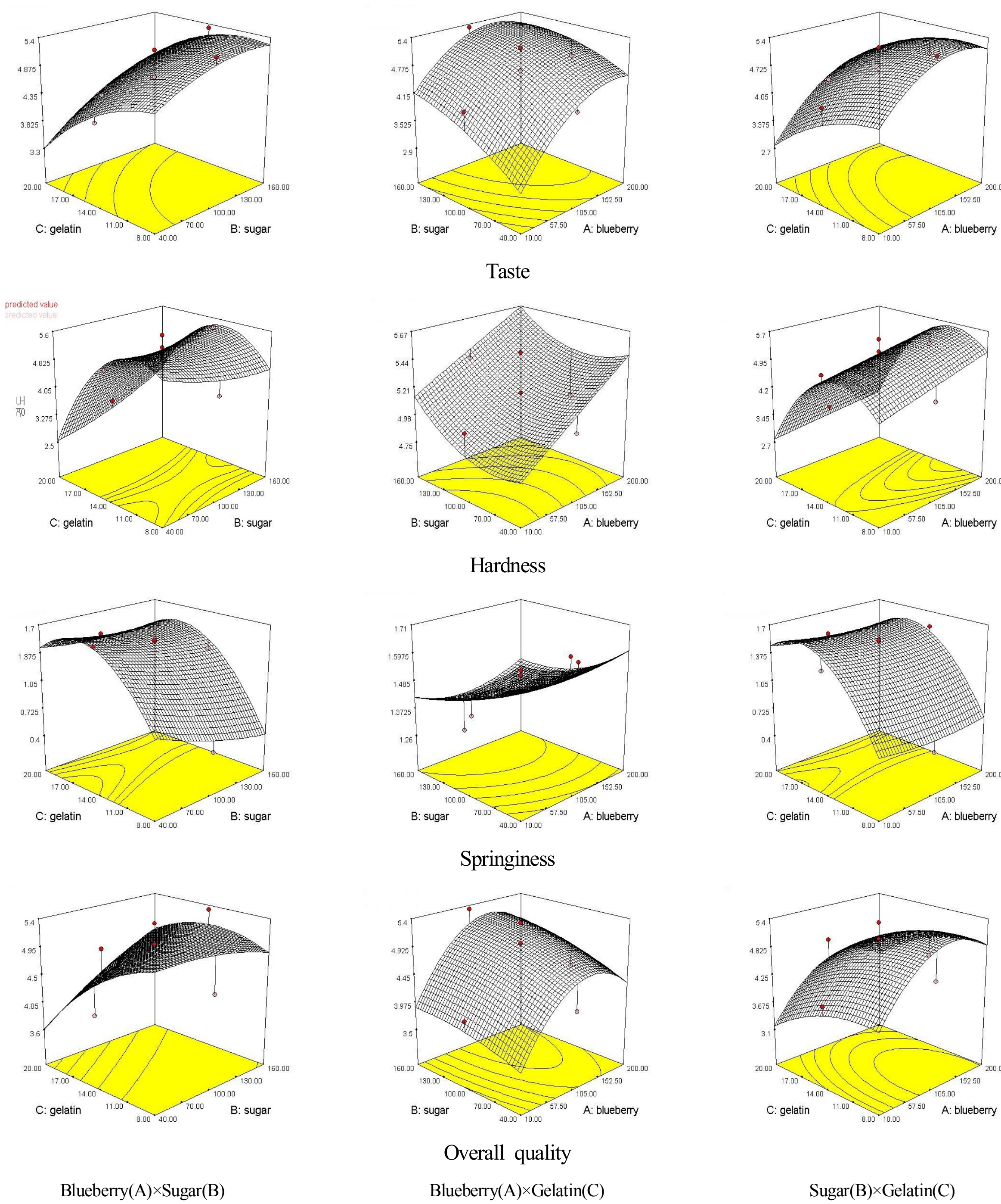
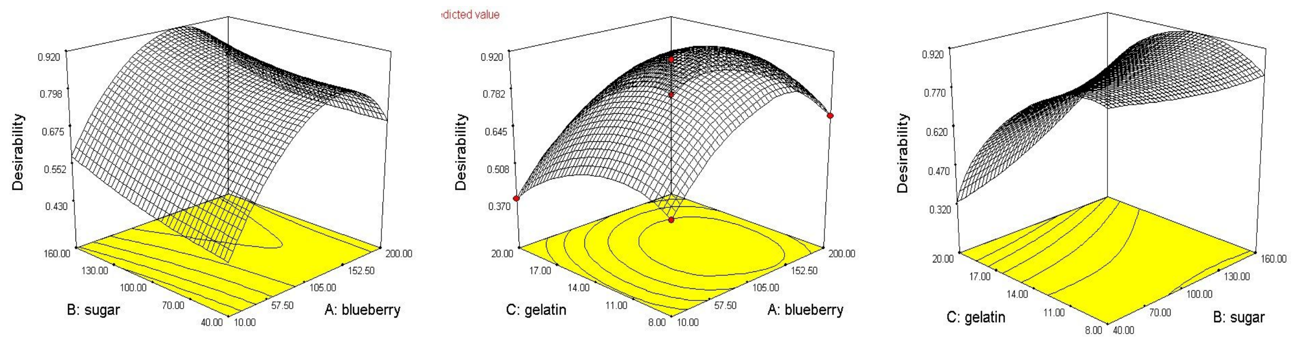


Fig. 1. Continued

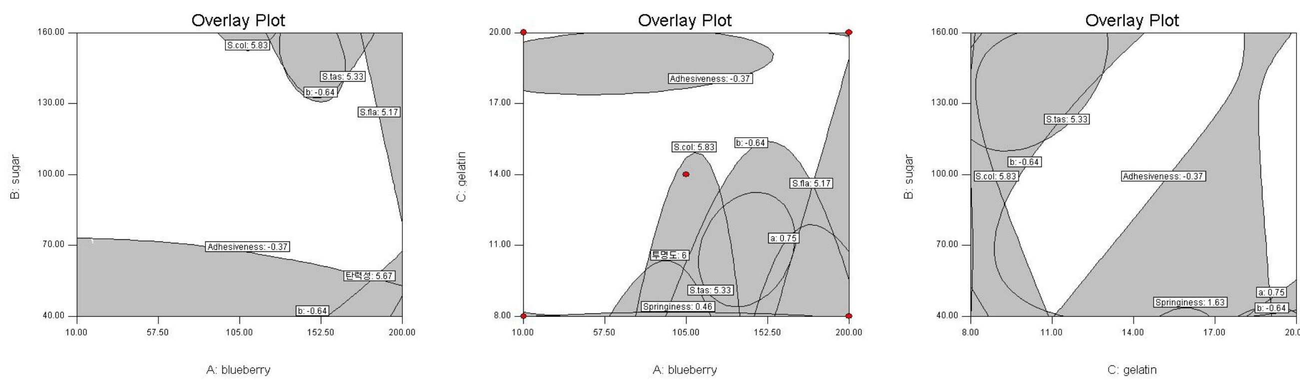
rability was deduced through point prediction, and the predicted optimal values were 133.63 g of blueberry juice, 160.00 g of sugar and for every 12.78 g of gelatin.

Central Composite Design was used for the purpose of optimizing the manufacturing conditions for blueberry jelly. The compositional and functional properties were measured, and these values were applied to a mathematical model. A canonical form and perturbation plot showed the influence of each ingredient on the final mixture product. The sensory evaluation results showed significant values in color (p<0.05), flavor (p<0.001), clarity (p<0.01), taste (p<0.01), hardness (p<0.01), springiness (p<0.01) and overall quality (p<0.05). Based on the overlapped part of



Blueberry(A)×Sugar(B) Blueberry(A)×Gelatin(C) Sugar(B)×Gelatin(C)

Fig. 2. Response surface plots for optimizing the mixture on desirability of blueberry jelly.



Blueberry(A)×Sugar(B) Blueberry(A)×Gelatin(C) Sugar(B)×Gelatin(C)

Fig. 3. Overlay plot of the common area for the optimization mixture of blueberry jelly.

categories (Figure 3), in range of factors that satisfy all sensory categories, the value located in the middle was calculated, and the optimization point was obtained which was found to be 133.63 g of blueberry juice, 160.00 g of sugar and for every 12.78 g of gelatin.

Through the results of this study, blueberry jelly was considered to be competitive in functionality, quality and preference. Optimization to determine the mixing ratios to satisfy consumer preferences and their evaluation will be the subject of further needed research.

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