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Optimization of Jelly Made with *Rubus coreanus* (Bokbunja) Using Response Surface Methodology

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Abstract

The purpose of this study was to find new applications for *Rubus coreanus* and to produce new products. Jelly prepared with *Rubus coreanus* was studied and analyzed with regard to its composition, rheology and sensory evaluation. The technique of response surface methodology was used to analyze the results, which showed 16 experimental points including 2 replicates for *Rubus coreanus* juice, gelatin and sucrose. Rheological characteristics such as lightness, redness, yellowness and hardness, springness, chewiness and gumminess were shown to be significant, and these were mostly influenced by the content of *Rubus coreanus* juice. Significant sensory characteristics such as color, flavor, transparency, taste and the overall quality were also found to be greatly influenced by *Rubus coreanus* juice and gelatin in general. Based on the overlapping categories of factors that satisfied all sensory categories, the maximally optimized point was taken as the middle point. This value was determined to be 43.28 g of *Rubus coreanus* juice and 9.19 g of gelatin for every 140.00 g of sucrose.

Key words: *Rubus coreanus*, jelly, response surface methodology, optimization, sensory evaluation

INTRODUCTION

With the current trend in diet habits and lack of exercise, individuals are suffering from diabetes, various types of cancers, diseases of circulatory organs and high blood pressure. There is thus a growing concern health foods in our society. One study demonstrated the beneficial effects of fruit and vegetable consumption on indices of health for a sample population (1). In particular antioxidants and phytochemicals in fruits and vegetables reduce the risk of several chronic and degenerative diseases (2).

The dried fruit of *Rubus coreanus* is well-known in Korea and is commonly referred to as "Bokbunja" (3). It has been employed as traditional medicine for centuries. *Rubus coreanus* contains a group of phytochemicals providing nutrients like phosphorus, iron, calcium, vitamin C, organic acids etc. and phenolic compounds like quercetin, ellagic acids and sanguiin H-5 (4). Pharmacological studies of *Rubus coreanus* have revealed that it is capable of suppressing *Vibrio cholerae*, *Tubercle bacillus*, *Staphylococcus aureus* (5,6). Antioxidant activity (7), an anti-cancer activator (8), increment in immunity activity, hormone secretion promotion, viral hepatitis type B inhibitive action and weight control effects (9) have been observed in *Rubus coreanus*.

Jellies are a widely consumed dessert, appreciated for their texture and ease of cooking. The use of natural ingredients, exhibiting special properties and providing specific health benefits, is a very attractive way to design new food products (10). The objectives of the present study were to assess the effects of three factors (*Rubus coreanus* juice, sucrose and gelatin) on the physicochemical characteristics of *Rubus coreanus* jellies using response surface methodology (RSM) and to determine the optimal level of each of these factors.

MATERIALS AND METHODS

Materials

Rubus coreanus grown in Gochang (Korea) was purchased directly from the producers. These were used in the study by squeezing the juice from *Rubus coreanus* (OSK, Korea) after putting them in a deep-freezer at -20°C. Also, sucrose (CJ, Korea), gelatin (Knox, USA) and citric acid (Shinwon industrial Co., Ltd., Korea) were used. Potable water was available at the processing site.

Experimental design

The Design Expert 7 Program was used to plan the study as well as for data analysis and optimization analysis of *Rubus coreanus* jelly. As independent variables,

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the three factors chosen were *Rubus coreanus* juice, gelatin and sucrose. As dependent variables, color values (L, a, b), textural evaluation (hardness, springiness, chewiness, gumminess, and cohesiveness) and sensory evaluation (color, flavor, transparency, taste, hardness, springiness, and overall quality) were chosen. Through pre-examination the maximum and minimum range of *Rubus coreanus* juice, sucrose and gelatin were determined to be 20～60 g, 8～16 g, 60～140 g respectively. *Rubus coreanus* juice and water were 400 g and citric acid was limited to 2 g. The experimental points of Central Composite consist of the most central point, ±αpoint (axial point) and ±1 level point (factorial point), and between these experimental points, there existed 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 (11). The mixture ratios for the jelly to *Rubus coreanus* juice are as shown in Table 1.

Preparation of jelly

The standard formulation for product treatment consisted of *Rubus coreanus* juice, water, gelatin, sucrose and citric acid. *Rubus coreanus* juice was mixed with water. The gelatin was dissolved using half of the mixed *Rubus coreanus* juice and water for 10 min. The remaining half of the mixed *Rubus coreanus* juice and water was boiled to 70°C. Afterward, the sucrose was added to the mixture and boiled to 100°C and then let to cool.

Next, the first half of the mixed *Rubus coreanus* juice and water were added to this solution and stirred at regular speed for 3 min, prior to addition of citric acid. The completed solution was placed in a container (15×15×4 cm), and solidified at room temperature for 1 hour and then refrigerated at 4°C for 5 hours. Finally, the jelly was cut into portions of equal size (2×2×3 cm).

Table 1. Experimental design for *Rubus coreanus* jelly

Sample No.[1)]	Variable level[2)]		
	X_1	X_2	X_3
1	20.00	8.00	60.00
2	60.00	8.00	60.00
3	20.00	16.00	60.00
4	60.00	16.00	60.00
5	20.00	8.00	140.00
6	60.00	8.00	140.00
7	20.00	16.00	140.00
8	60.00	16.00	140.00
9	20.00	12.00	100.00
10	60.00	12.00	100.00
11	40.00	8.00	100.00
12	40.00	16.00	100.00
13	40.00	12.00	60.00
14	40.00	12.00	140.00
15	40.00	12.00	100.00
16	40.00	12.00	100.00

[1)]Sample No. : The number of experimental conditions by central composite design.
[2)]X_1: *Rubus coreanus* juice, X_2: gelatin, X_3: sucrose.

Color measurement

The color values (L, a, and b value) of the *Rubus coreanus* 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.

Texture analysis

The texture of *Rubus coreanus* jelly was measured using a texture analyzer (model TAXT express, Stable Micro system Ltd., UK). TPA parameters (hardness, springiness, chewiness, gumminess, and cohesiveness) were calculated. The operating conditions of the texture analyzer are shown in Table 2.

Sensory evaluation

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

Optimization

Through numerical optimization of a Canonical Model and graphical optimization, the optimal quantities of *Rubus coreanus* juice, sucrose and gelatin was chosen, by selecting the optimal point 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 using

Table 2. Operating conditions for texture analyzer

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

the following formula.

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

Here, D is the overall desirability, d is each desirability and n is the number of responses.

Statistical analysis

Statistical analysis of variance (ANOVA) and multiple regressions 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.

RESULTS AND DISCUSSION

Physicochemical characteristics

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

Color values: The color values from 16 conditions with 3 variables are listed 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 within the ranges of 19.14～24.43, 0.93～2.56 and -0.51～-0.11, respectively. Increased *Rubus coreanus* juice significantly decreased L ($p<0.01$), a ($p<0.05$) and b ($p<0.05$). Shown in Fig. 1 is the response surface for the effect of *Rubus coreanus* juice, gelatin and sucrose on color values of the *Rubus coreanus* jelly.

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 described in Table 4. Significant values in hardness ($p<0.001$), springiness ($p<0.01$), chewiness ($p<0.01$), gumminess ($p<0.05$) are shown. Moreover, the addition of gelatin had a positive effect on the texture analyzer. Increased gelatin significantly increased the texture parameters. These results were in accordance with a previous study in which the texture of Noni jelly was estimated by a subjective method and was shown to be influenced by the content of gelatin (12). The correlation between ingredients and the cohesiveness of jelly with *Rubus coreanus* was not significant. Shown in Fig. 2 is the response surface for the effect of *Rubus coreanus* juice, gelatin and sucrose on textural characteristics of *Rubus coreanus* jelly.

Sensory evaluation

The values of color, flavor, transparency, taste, hardness, springiness and overall quality were within the ranges of 3.67～5.33, 3.67～5.50, 2.67～6.33, 2.83～5.17, 3.33～5.33, 2.83～5.17, 3.17～5.67, respectively (Table 5). The model equations and coefficients of determination of the model equation are given in Table 6. The sensory evaluation results showed significant values in color ($p<0.01$), flavor ($p<0.01$), transparency ($p<0.001$), taste ($p<0.05$) and overall quality ($p<0.01$). An

Table 3. Experimental combinations and data under various conditions of *Rubus coreanus* juice, gelatin, sucrose, 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
1	20	8	60	19.14	1.98	-0.25	2219.30	0.42	161.65	400.04	0.18
2	60	8	60	19.90	2.19	-0.21	1622.73	0.40	141.71	364.52	0.22
3	20	16	60	21.42	1.83	-0.33	4972.03	0.57	565.04	945.11	0.20
4	60	16	60	19.32	1.47	-0.33	5072.87	0.59	641.49	1065.54	0.22
5	20	8	140	24.00	2.34	-0.25	4425.15	0.33	369.26	1141.42	0.26
6	60	8	140	24.43	0.94	-0.51	3006.21	0.43	780.05	1836.20	0.31
7	20	16	140	22.46	2.02	-0.22	5616.23	0.85	1556.32	1831.85	0.33
8	60	16	140	20.83	0.93	-0.28	6560.30	0.72	819.15	1133.56	0.17
9	20	12	100	21.79	2.22	-0.16	5184.13	0.75	878.03	1170.97	0.23
10	60	12	100	22.80	2.37	-0.17	3639.27	0.65	540.40	835.22	0.23
11	40	8	100	23.08	2.31	-0.17	2770.97	0.46	355.19	763.68	0.27
12	40	16	100	20.28	1.83	-0.11	5535.93	0.74	1577.88	2135.69	0.39
13	40	12	60	21.62	2.56	-0.15	4068.80	0.73	667.94	915.48	0.22
14	40	12	140	23.38	2.00	-0.23	4943.27	0.67	965.20	1442.58	0.29
15	40	12	100	22.74	2.34	-0.21	3731.67	0.68	696.25	1021.91	0.27
16	40	12	100	22.74	2.15	-0.14	3667.40	0.74	801.16	1086.07	0.30

[1)]Sample No.: The number of experimental conditions by central composite design.
[2)]X_1: *Rubus coreanus* juice (20～60 g), X_2: gelatin (8～16 g), X_3: sucrose (60～40 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: hardness, Y_5: springiness, Y_6: chewiness, Y_7: gumminess, Y_8: cohesiveness.

Table 4. Analysis of the predicted model equation for the color values and textural characteristics of *Rubus coreanus* jelly

Responses[1)]	Model	R-squared	F-value	P-value Prob > F[2)]	Equation of on terms of pseudo component[3)]
Y_1	2FI	0.8089	6.35	0.0074**	$21.87-0.15X_1-0.62X_2+1.37X_3-0.61X_1X_2+0.018X_1X_3-0.86X_2X_3$
Y_2	Quadratic	0.8650	4.27	0.0456*	$2.37-0.25X_1-0.17X_2-0.18X_3-0032X_1X_2-0.29X_1X_3+0.068X_2X_3-0.13X_1^2-0.36X_2^2-0.15X_3^2$
Y_3	Quadratic	0.8667	4.34	0.0441*	$-0.13-0.029X_1+0.012X_2-0.022X_3+0.020X_1X_2-0.045X_1X_3+0.058X_2\ X_3-0.053X_1^2-0.028X_2^2-0.078X_3^2$
Y_4	2FI	0.8962	12.95	0.0006***	$4002.27551.55X_1+1671.30X_2+359.54X_3+757.55X_1X_2-372.39X_1X_3+192.79X_2X_3$
Y_5	Quadratic	0.9352	9.62	0.0061**	$0.72-0.013X_1+0.14X_2+0.029X_3-0.024X_1X_2-3.750E-003X_1X_3+0.059X_2X_3-0.027X_1^2-0.13X_2^2-0.027X_3^2$
Y_6	Linear	0.6757	8.34	0.0029**	$719.79-60.75X_1+335.20X_2+231.21X_3$
Y_7	Linear	0.5793	5.51	0.0130*	$1130.62-25.43X_1+260.59X_2+369.49X_3$

[1)]Y_1: L (white +100↔0 black), Y_2: a (red +60↔-60 green), Y_3: b (yellow +60↔-60 blue), Y_4: hardness, Y_5: springiness, Y_6: chewiness, Y_7: gumminess.
[2)]*p<0.05, **p<0.01, ***p<0.001.
[3)]X_1: *Rubus coreanus* juice (g), X_2: gelatin (g), X_3: sucrose (g).

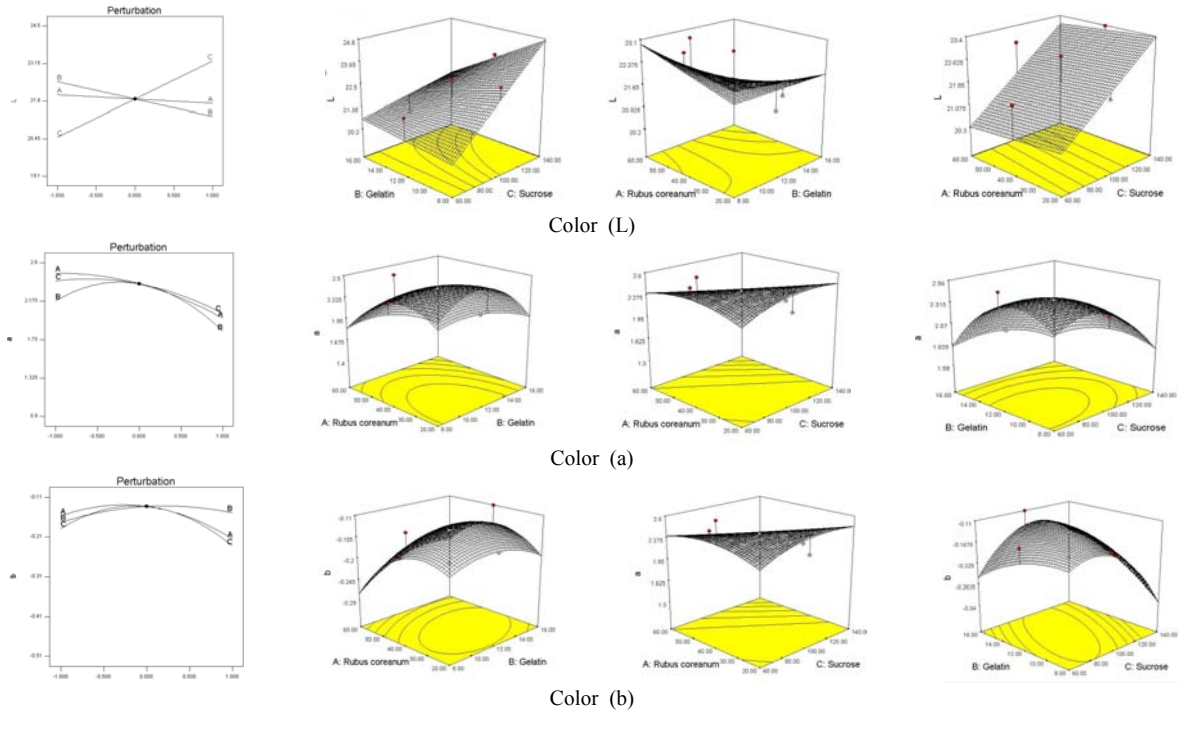


Fig. 1. Response surfaces for the effect of *Rubus coreanus* juice (A), gelatin (B), sucrose (C) on color of *Rubus coreanus* jelly.

increase in *Rubus coreanus* juice decreased the preference in color. But, as more sucrose was added, the preference in color increased. A larger portion of *Rubus coreanus* juice increased the preference in flavor. It was shown that with more *Rubus coreanus* juice, the transparency of the jelly decreased. Addition of gelatin and sucrose showed little influence on flavor or transparency.

A greater addition of *Rubus coreanus* juice increased the preference in taste. But, as more gelatin was added, the preference in taste decreased; sucrose had little influence on the taste. Correlation between ingredients and the hardness and springiness of jelly with *Rubus coreanus* were not significant. The texture characteristic of gel, hardness and springiness were not significant but

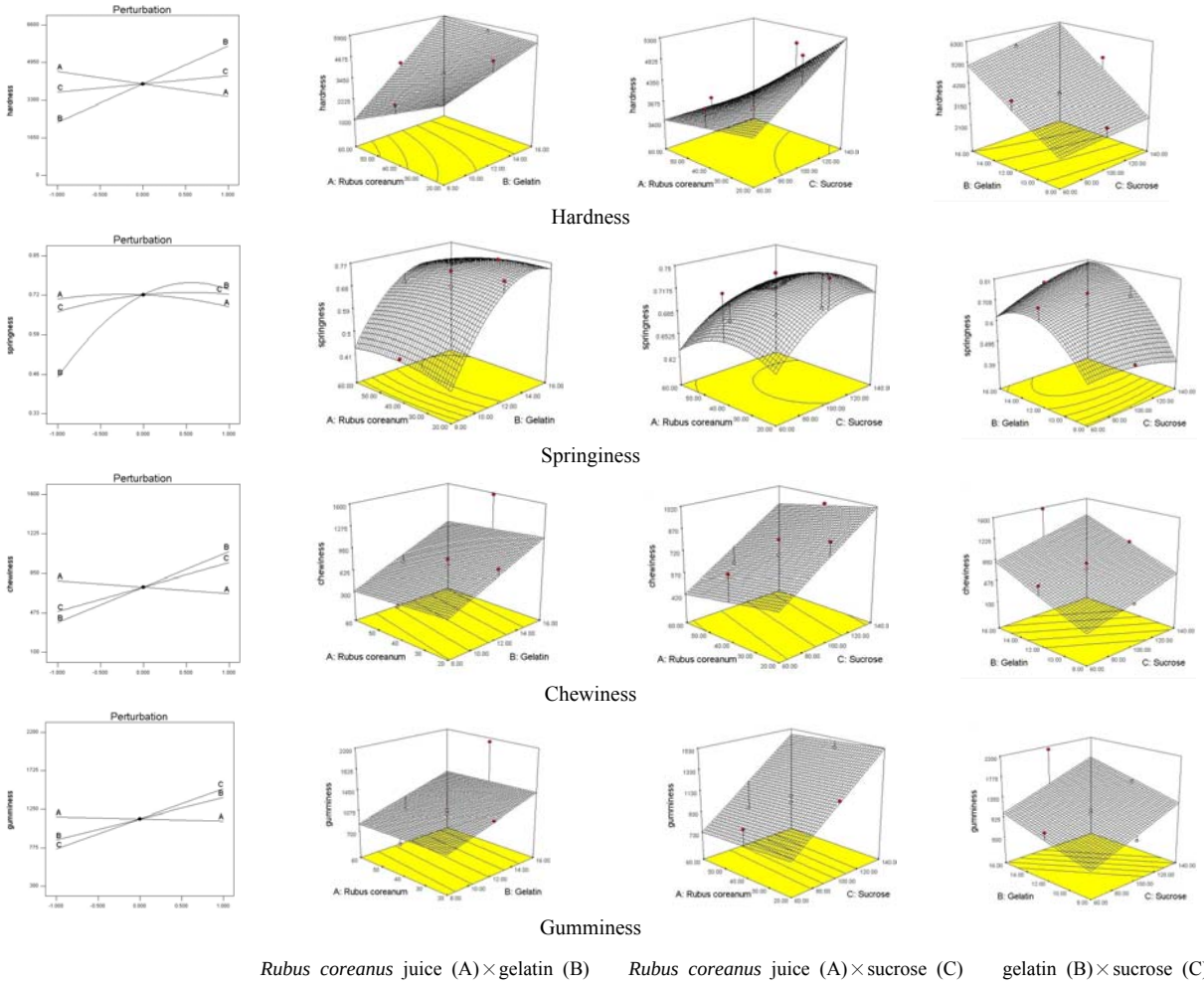


Fig. 2. Response surfaces for the effect of *Rubus coreanus* juice (A), gelatin (B), sucrose (C) on textural characteristics of *Rubus coreanus* jelly.

Table 5. Experimental combinations and data under various conditions of *Rubus coreanus* juice, gelatin, sucrose, 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	20	8	60	4.17	3.83	4.83	4.33	4.17	3.67	4.00
2	60	8	60	4.50	5.00	3.50	3.33	3.67	3.50	3.83
3	20	16	60	4.33	4.17	5.33	3.00	4.67	4.33	3.83
4	60	16	60	4.17	4.67	3.67	3.83	5.33	5.17	3.17
5	20	8	140	5.33	3.67	5.33	4.50	3.33	3.17	4.17
6	60	8	140	4.17	4.50	4.17	5.17	5.00	5.00	4.33
7	20	16	140	5.00	3.83	5.33	3.00	4.17	4.33	4.50
8	60	16	140	4.33	5.50	3.17	4.33	4.17	4.33	3.17
9	20	12	100	5.33	3.67	6.33	4.83	4.83	4.50	4.17
10	60	12	100	3.67	5.33	2.67	4.50	4.83	5.00	4.17
11	40	8	100	4.67	4.83	5.00	4.67	4.00	2.83	4.17
12	40	16	100	4.67	4.33	4.33	4.33	5.17	5.00	4.50
13	40	12	60	5.00	4.33	3.83	4.50	5.17	5.17	4.50
14	40	12	140	5.17	4.17	4.83	5.00	4.83	5.17	4.67
15	40	12	100	4.50	3.67	4.33	4.67	4.83	4.17	5.67
16	40	12	100	4.17	4.33	3.83	2.83	4.33	4.17	3.17

[1)]Sample No.: The number of experimental conditions by central composite design.
[2)]X_1: *Rubus coreanus* juice (20～60 g), X_2: gelatin (8～16 g). X_3: sucrose (60～140 g).
[3)]Y_1: color, Y_2: flavor, Y_3: transparency, Y_4: taste, Y_5: hardness, Y_6: springiness, Y_7: overall quality.

Table 6. Analysis of the predicted model equation for the sensory characteristics of *Rubus coreanus* jelly

Responses[1)]	Model	R-squared	F-value	P-value Prob> F[2)]	Equation of on terms of pseudo component[3)]
Y_1	Linear	0.6483	7.37	0.0046*	$4.49-0.49X_1-0.043X_2+0.26X_3$
Y_2	Linear	0.6839	8.65	0.0025**	$4.36+0.58X_1+0.067X_2-0.033X_3$
Y_3	Linear	0.7582	12.54	0.0005***	$4.41-1.00X_1-0.100X_2+0.17X_3$
Y_4	Linear	0.5862	5.67	0.0118*	$4.45+0.41X_1-0.41X_2+0.046X_3$
Y_5	Quadratic	0.9653	18.54	0.0010***	$5.34+0.042X_1-0.068X_2+0.13X_3-0.11X_1X_2-0.21X_1X_3+0.062X_2X_3-1.10X_1^2-0.35X_2^2-0.097X_3^2$

[1)]Y_1: color, Y_2: flavor, Y_3: transparency, Y_4: taste, Y_5: overall quality.
[2)]Linear *$p<0.05$, **$p<0.01$, ***$p<0.001$.
[3)]X_1: *Rubus coreanus* juice (g), X_2: gelatin (g), X_3: sucrose (g).

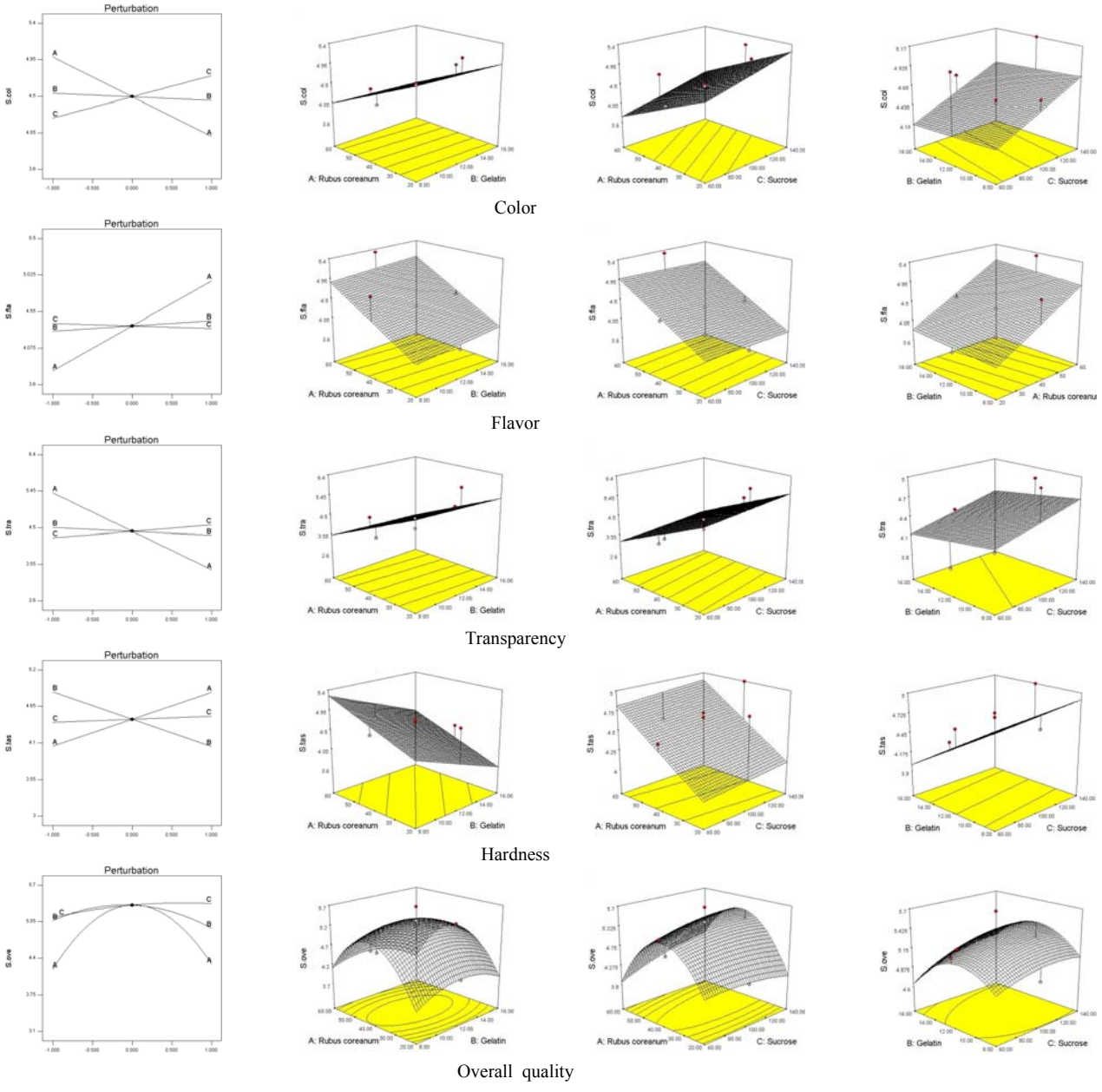
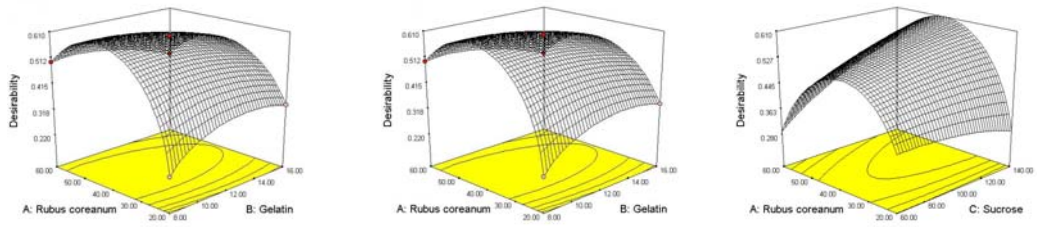


Fig. 3. Response surfaces for the effect of *Rubus coreanus* juice (A), gelatin (B), sucrose (C) on sensory characteristics of *Rubus coreanus* jelly.



Rubus coreanus juice (A) × gelatin (B) *Rubus coreanus* juice (A) × sucrose (C) gelatin (B) × sucrose (C)

Fig. 4. Response surfaces plots for optimizing the mixture on desirability of *Rubus coreanus* jelly.

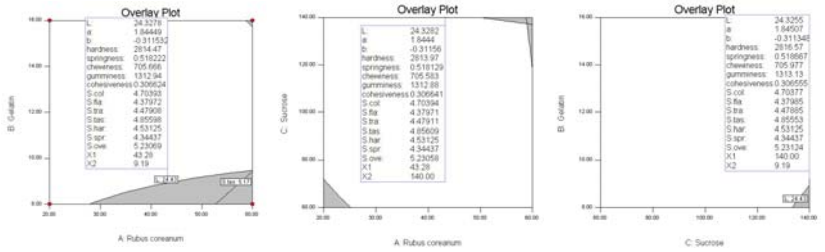


Fig. 5. Overlay plot of the common area for the optimization of the mixture of *Rubus coreanus* jelly.

the addition of *Rubus coreanus* juice had a positive effect on the sensory evaluation results.

It was shown that the increased addition of *Rubus coreanus* juice initially improved the overall quality of thejelly, but as more juice as added the overall quality then declined. An increased addition of gelatin contributed to a decreased overall quality of the final product; additional sucrose showed little influence on the overall quality of the jelly. Shown in Fig. 3 is the response surface for the effect of *Rubus coreanus* juice, gelatin and sucrose on sensory characteristics on *Rubus coreanus* jelly.

Optimization

The optimal amounts of *Rubus coreanus* juice, gelatin and sucrose were selected through numerical optimization of a canonical model and through graphical optimization. The significant items shown in the sensory evaluation were determined by their maxima. This was taken from the response formula determined by the modeling. The numerical point was selected through numerical optimization (Fig. 4) and graphical optimization (Fig. 5). The optimal point with the highest desirability was deduced through point prediction, and the predicted optimal values were 43.28 g of *Rubus coreanus* juice and 9.19 g of gelatin for every 140.00 g of sucrose.

CONCLUSIONS

Central Composite Design was used for the purpose of optimizing the manufacturing conditions for *Rubus coreanus* 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 product. The sensory evaluation results showed significant values in color ($p<0.01$), flavor ($p<0.01$), transparency ($p<0.001$), taste ($p<0.05$) and overall quality ($p<0.001$). The optimal sensory ratio was determined to be 43.28 g of *Rubus coreanus* juice and 9.19 g of gelatin for every 140.00 g of sucrose.

Through the results of the present study, *Rubus coreanus* jelly was considered to be competitive compared to existing products in functionality, quality and preference. Optimization of the mixing ratios are required to satisfy consumer preferences and their evaluation will be the subject of further research.

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REFERENCES

1. Devareddy L, Hooshmand S, Collins JK, Lucas EA, Chai SC, Arjmandi BH. 2008. Blueberry prevents bone loss in ovariectomized rat model of postmenopausal osteoporosis. *J Nutr Biochem* 19: 694-699.
2. Murphy RR, Renfroe MH, Brevard PB, Lee RE, Gloechner JW. 2007. Cooking did not decrease antioxidant capacity of wild blueberries. *J Am Diet Assoc* 107: A53.
3. Bae GH. 2000. *The Medicinal Plants of Korea*. Kyohak Publishing Co., Seoul, Korea. p 231.
4. Pang, GC, Kim MS, Lee MW. 1996. Hydrolyzable tannins from the fruits of *Rubus coreanus*. *Korean J Pharmacogn* 27: 366-370.
5. Kim HC, Lee SI. 1991. Comparision of the pharmacological effect of kinds *Rubi fructus*. *Korean J Herbology* 6: 3-12.
6. Costantino L, Albasini A, Rasteli G, Benvenuti S. 1992. Activity of polyphenolic crude extracts as scavengers of superoxide radicals and inhibitors of xanthine oxidase.

Plant Med 58: 342-435.
7. Kahkonen MP, Hopia AI, Vuorela HJ, Rauha JP, Pihlaja K, Kujala TS, Heinonen M. 1999. Antioxidant activity of plant extracts containing phenolic compounds. *J Agric Food Chem* 47: 3954-3962.
8. De Ancos B, Gonzalez EM, Cano MP. 2000. Ellagic acid, vitamin C and total phenolic contents and radical scavenging capacity affected by freezing and frozen storage in raspberry fruit. *J Agric Food Chem* 48: 4565-4570.
9. Kwon KH, Cha WS, Kim DC, Shin HJ. 2006. A research and application of active ingredients in Bokbunja (*Rubus coreanus Miquel*). *Korean J Biotechnol Bioeng* 21: 405-409.
10. Gouveia L, Batishts AP, Miranda A, Empis J, Raymundo A. 2007. Chlorella vulgaris biomass used as colouring source in traditional butter cookies. *Inn Food Sci Emerg Technol* 8: 433-436.
11. Park SP, Joo NM. 2006. Optimization of jelly with addition of *Morinda citrifolia* (Noni) by response surface methology. *Korean J Food Cookery Sci* 22: 1-11.
12. Han GH. 2004. Stimulation and the establishment of optimization in new product development using food by product. *PhD Dissertation.* Kyunggi University, Korea. p 4-5.

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