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Optimization of Pan Bread Prepared with Ramie Powder and Preservation of Optimized Pan Bread Treated by Gamma Irradiation during Storage

Heejeong Lee and Nami Joo†

Department of Food and Nutrition, Sookmyung Women's University, Seoul 140-742, Korea

Abstract

This study was conducted to develop an optimal composite recipe for pan bread with ramie powder that has high sensory approval with all age groups and to estimate the DPPH radical scavenging activity and the pan bread shelf life after gamma irradiation. The sensory evaluation results showed significant differences in flavor ($p<0.05$), appearance ($p<0.01$), color ($p<0.01$), moistness ($p<0.01$), and overall quality ($p<0.05$) based on the amount of ramie powder added. As a result, the optimum formulations by numerical and graphical methods were calculated to be as follows: ramie powder 2.76 g (0.92%) and water 184.7 mL. Optimized pan bread with ramie powder and white pan bread were irradiated with gamma-rays at doses of 0, 10, 15, and 20 kGy. The total bacterial growth increased with the longer storage time and the least amount of ramie powder added. Consequently, these results suggest that the addition of ramie powder to pan bread provides added value to the bread in terms of increased shelf life.

Key words: ramie, optimization, response surface methodology (RSM), gamma-irradiation, DPPH radical scavenging activity

INTRODUCTION

Ramie (*Boehmeria nivea* L.), a flowering plant with a unique scent, is in the nettle family Urticaceae and is native to eastern Asia (1). Ramie is one of the oldest fiber crops and is principally used for fabric production. Ramie has been consumed in a sterile year and is used in Korean traditional medicine for treatment of diarrhea and snake bites (2). Koreans often consume ramie in the form of rice-cake or as a tea. Ramie extract has high-quality physiological functions, such as antioxidant activity that prevents both bacterial and fungal attacks, and also antitumorigenic effects on lung and liver cancer (3).

In Korea, some researchers have used the extracts on various tteok (traditional Korean rice cakes) (4) such as jeolpyun (5) and sulgidduk (6). In addition, a study using ramie is being conducted for diverse food resources (7). However, the baking studies on the use of ramie lack depth because they only include the muffin (8) and cookie (9). There are already several baking studies for pan bread that incorporate functional substitutes, such as pomegranate powder (10), *Nelumbo nucifera* G. tea powder (11), *Enteromorpha intenstinalis* (12), *Corni fructus* flour (13), persimmon leaf powder (14), green tea (15), mugwort powder (16), and red ginseng marc powder (17).

The bactericidal effect of bioactive additives to the pan bread, such as ramie in the case of this study, is also something to be considered and compared to the effect of irradiation. Irradiation has a strong bactericidal effect that can be used to eliminate microorganisms that cause food spoilage and food-borne illnesses, and to extend shelf life (18). In addition, there have not been studies on the effect of gamma irradiation on qualities of food storage.

The objectives of the present study were to assess the effects of two factors (ramie powder and water) on the physicochemical characteristics of ramie pan bread by using response surface methodology (RSM) and to determine the optimal level of each of these factors. The optimized pan bread with ramie powder treated by gamma irradiation was to be evaluated on the DPPH radical activity and microbiological effects during storage.

MATERIALS AND METHODS

Materials

Ramie (*Boehmeria nivea* L.) leaves were purchased from the Ramie Association, Hansan Co. of Hansan Ramie Fabric Cultural Festival, Seocheon-gun, Chungnam, South Korea. The strong wheat flour (ranked 1st; CJ Corp., Seoul, Korea), granulated sugar (CJ Corp.), unsalted butter (Seoul Milk Corp., Seoul, Korea), salt (CJ Corp.), whole milk powder (Seoul Milk Corp.) and Fresh yeast (Jenico Corp., Seoul, Korea) were utilized.

†Corresponding author. E-mail: 00nutrition@sookmyung.ac.kr
Phone: +82-2-710-9471, Fax: +82-2-710-9479

Analysis of proximate composition

Compositional properties of the ramie powder were investigated by using AOAC (19). Moisture content was determined by weight loss after 12 hr of drying at 105°C in a drying oven (SW-90D, Sang Woo Scienctific Co., Bucheon, Korea). Fat contents were determined by Soxhlet method with a solvent extraction system (Soxtec ®Avanti 2050 Auto System, Foss Tecator AB, Höganas, Sweden) and protein was determined by Kjeldahl method with an automatic Kjeldahl nitrogen analyzer (Kjeltec ®2300 Analyzer Unit, Foss Tecator AB). Ash was determined according to AOAC method 923.03 Carbohydrate contents were calculated by the difference among the parameters.

Experimental design

The Design-Expert 7 Program (Stat-Easy Co., Minneapolis, MN, USA) was used for the establishment of a study plan, data analysis and optimization analysis of ramie pan bread. Optimization analysis of quality planed Central Composite design of response surface methodology. As independent variables, the two factors chosen were Ramie power and water.

Through a pre-examination, the maximum and minimum ranges of ramie powder and water were determined to be 1.5～9 g and 160～200 mL, respectively (Table 1). The experimental points of Central Composite consist of the most central point, ±α point (axial point) and ±1 level point (factorial point), and between these experimental points, there exists an iterative point for the selection of a mode and the verification of lack of fitness. Accordingly, when each established scope was inputted, forming 10 experimental points, 2 iterative points were selected through the establishment of replication (20). The mixture ratios for ramie pan bread to straight dough method are as shown in Table 1. Excluding butter mixed in a Kitchen Aid mixer (5KSM150PS, Kitchen Aid Co., St. Joseph, MI, USA) until the gluten development reached the optimal condition, butter was added at the clean-up stage in 13 min. Optimally mixed dough was fermented for 40 min at 27°C and 75% RH (Panem, La Crèche, France), the bread samples were cut to a size of 125×125×170 mm (divided into two pieces), molded and sheeted by hand, placed in pans, proofed for 40 min at 35°C and 85% RH, and baked for 30 min at 200°C/180°C (Daeyung, Seoul, Korea).

Specific volume and baking loss rate

The baked bread was cooled to room temperature for 2 hr. The bread loaf volume was measured by seed displacement method (21), and the ratio of volume to mass (specific volume) was calculated by dividing loaf volume by loaf weight (22).

$$\text{Specific volume (mL/g)} = \frac{\text{Loaf volume (mL)}}{\text{Loaf weight (g)}}$$

After baking and cooling (2 hr), baking loss was measured as follows.

$$\text{Baking loss} = \text{DW (dough weight)} - \text{BW (bread weight)}$$

$$\text{Baking loss rate} = \frac{\text{DW} - \text{BW}}{\text{DW}} \times 100$$

Color measurement and texture analysis

The color values of ramie pan bread, baking and cooling (2 hr), crust and crumb were measured using a Color difference meter (Colormeter CR-200, Minolta Co., Osaka, Japan). The slices of bread (10 mm) were cut from the center of the loaf. The color difference meter was calibrated by using a standard white plate with L (lightness), a (redness), and b (yellowness) values of 97.32, +0.07, and +1.70, respectively. Color was measured at the same location (one in the center and three at the edges) using three baked pan bread for each treatment and mean values were reported.

The texture of ramie pan bread was measured using a texture analyzer (TA-XT2, Stable Micro Systems Ltd., Godalming, England) equipped with 3.5 cm diameter (SMS P/7.5) plunger. TPA (hardness, springiness, cohe-

Table 1. Experimental design for pan bread with ramie powder (unit: g)

Sample No.[1)]	Factor		Wheat flour	Sugar	Butter	Fresh yeast	Powder milk	Salt
	Ramie powder	Water						
1	1.50	160	298.50	18	12	10	9	6
2	9.00	160	291.00					
3	1.50	200	298.50					
4	9.00	200	291.00					
5	1.50	180	298.50					
6	9.00	180	291.00					
7	5.25	160	294.75					
8	5.25	200	294.75					
9	5.25	180	294.75					
10	5.25	180	294.75					

[1)]Sample No.: The number of experimental conditions by central composite design.

siveness, gumminess, and chewiness) parameters were calculated. The texture was measured at the same experimental design using three baked pan bread (after baking and cooling 1 hr, crumb slices 30×30×30 mm), after which mean values were reported.

Sensory evaluation

Sensory evaluation was conducted after cooling loaf for 2 hr at room temperature. The slices of bread with 30×30×30 mm were cut from the center of the loaf. A panel consisting of 10 students at Sookmyung Women's University was chosen. The panelists were asked to score the color, flavor, appearance, moistness, and overall quality of the ramie pan bread with points ranging from 1 (dislike extremely) to 7 (like extremely). The ramie pan bread prepared for each test sample.

Optimization

Through the numerical optimization of a Canonical model and graphical optimization, the quantity of ramie powder and water was chosen for the optimal result, by which the optimal point was selected by using the point found through the point prediction. For the numerical optimization, the goal area was set with the highest point of the sensory test out of all reactions with the coefficients of the model using the standard canonical model.

The optimal points presented through numerical optimization, the optimal point showing the highest desirability were selected after acquiring the desirability through the following formula.

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

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

Gamma irradiation

A comprehensive study on high-dose irradiated, ready-to-eat (RTE) food has been underway in Korea since 2000 (23,24). The purpose of the study described here was to compare non-irradiated and the high-dose irradiated pan breads. Gamma irradiation was carried out in a ^{60}Co irradiator at Advanced Radiation Technology Institute (ARTI, Jeongeup, Korea) in the Korean Atomic Energy Research Institute doses ranging from 0 to 20 kGy for the prepackaged samples of optimized pan bread with ramie powder and white pan bread.

DPPH radical scavenging activity during storage

The DPPH radical scavenging activity was carried out according to the method described by Choi et al. (25) with a slight modification at 517 nm with a UV-visible spectrophotometer (Jasco V-530 UV VIS Spectrophotometer, Easton, MD, USA) for the prepackaged samples of optimized pan bread with ramie powder and white pan bread during 10 days storage. The percentage of 2,2-diphenyl-1-picryl-hydrazyl (DPPH) radical scavenging was obtained from the following equation:

Radical-scavenging activity=[1−(absorbance value of testing solution/absorbance value of control solution)] ×100

All samples were analyzed in triplicate.

Bacterial analysis during storage

Total plate counts were determined by a standard spread-plate method at 0, 1, 3, 5, 7, and 9 days of storage. Triplicate samples of pan bread were tested for each treatment. Two grams of pan bread samples (optimized pan bread with ramie powder and white pan bread) was mixed with 18 mL sterile water (0.85% NaCl) in a stomacher bag and agitated for 120 sec after closing the bag. A 1-mL aliquot was serially diluted into 9 mL sterile buffered peptone water (Difco, Detroit, MI, USA) and then 0.1 mL was placed on tryptic soy agar (Difco, Detroit). The plates were incubated upside down at 37±1°C for 48 hr and then counted. All experiments were conducted in triplicates.

Statistical analysis

Statistical analysis of variance (ANOVA) and multiple regression were performed using the Design-Expert 7 program (Stat-Easy Co., Minneapolis, MN, USA) 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

Proximate composition

The moisture, crude protein, crude lipid, crude carbohydrate, and crude ash contents of ramie powder were 6.66%, 23.82%, 7.82%, 48.27%, and 13.42%, respectively (Table 2). These values were in similar ranges with those of Lee et al. (1). The levels of protein, lipid, and ash contents were reported at 24.49%, 4.89%, and 11.41%,

Table 2. Proximate composition of ramie powder

Overall composition (%)				
Moisture	Crude protein	Crude lipid	Carbohydrate	Crude ash
6.66±0.50	23.82±2.09	7.82±0.51	48.27±1.56	13.42±0.16

respectively.

Meanwhile, Jung (16) reported the levels of protein, lipid and ash of mugowort were 1.98%, 4.65%, and 5.85 %, respectively. Lee et al. (26) reported the levels of protein of mulberry and persimmon leaves were 12% and 11.23%, respectively. Therefore, the ramie had a higher amount of protein than mugwort, mulberry, and persimmon.

Physical characteristics

Using Central Composite Design, the results of physical measurements from 10 conditions with 2 variables were obtained as shown in Table 3 with the purpose of optimizing the manufacturing conditions for pan bread with ramie. The model equations and the coefficients of determination of the model equation are given in Table 4. The weight values of ramie pan bread were in the ranges of 453～497 g. The maximum high was found with 1.5 g ramie powder and 160～180 mL water. The response surface for the effect of ramie powder and water on height, volume and specific volume is shown in Fig. 1. The data show that volume ($p<0.01$) and specific volume ($p<0.001$) decreased significantly with an increase in ramie powder and a decrease in water. Similar results of white bread made with persimmon leaf powder (14), green tea (15), mugwort powder (16) and red ginseng marc powder (17) were also showed the effects of ingredients upon volume differences. Height decreased significantly with an increase in ramie powder ($p<0.05$). A similar decrease in the height of white bread made with green tea was also reported (15); however, the baking loss rate was not significant.

Color value

The results of color values from 10 conditions with 2 variables are listed in Table 5. The model equations and the coefficients of determination of the model equation are given in Table 6. The values of L, a and b in crumb were in the ranges of 41.48～66.19, -1.96～-3.17, and 18.96～27.04, respectively (Table 5). Crust values were 30.99～42.61, 8.41～14.32, and 15.61～24.52, respectively. The analysis of L in crumb shows that lightness decreased significantly with an increase in ramie powder ($p<0.001$), but the changes in the crust were not significant. The a values in crumb significantly increased with additional ramie powder ($p<0.01$) but the crust a values were significantly decreased ($p<0.05$). The b values in crumb decreased significantly with an increase in ramie powder and a decrease in water ($p<0.05$); however, the changes in crust values were again not significant. The response surface for the effect of ramie powder and water on color (L, a, b) on white bread are shown in Fig. 2. Similar results in the L value of pan bread made with mugwort powder (16) or *Salicornia heracea* L. powder (27) were also reported, showing the effects of the different ingredients in chromaticity.

Table 3. Physical properties of pan bread with ramie powder

No.	Ramie powder	Water	Responses				
			Weight (g)	Height (cm)	Volume (cc)	Specific volume (cm^3/g)	Baking loss rate (%)
1	1.50	160	453.0±2.64[1)]	12.0±0.50[e2)]	1425±5.56[f]	3.15±0.02[g]	9.40±1.47
2	9.00	160	470.0±6.24	8.0±0.10[a]	1020±1.32[a]	2.17±0.03[a]	8.20±1.92
3	1.50	200	458.5±3.04	9.5±0.30[cd]	1690±8.66[j]	3.69±0.01[i]	12.67±1.40
4	9.00	200	479.5±0.86	9.2±0.20[bc]	1435±2.64[g]	2.99±0.00[f]	6.89±0.41
5	1.50	180	472.5±2.78	11.0±1.00[d]	1625±4.00[i]	3.44±0.02[h]	7.35±0.91
6	9.00	180	496.0±6.00	8.0±0.20[a]	1310±3.00[c]	2.64±0.03[c]	7.29±0.98
7	5.25	160	467.5±1.32	8.0±0.10[a]	1060±1.73[b]	2.27±0.01[b]	8.69±0.58
8	5.25	200	497.0±6.24	8.8±0.20[bc]	1550±2.00[h]	3.12±0.03[g]	8.72±1.25
9	5.25	180	476.5±2.29	9.0±0.20[bc]	1385±2.78[e]	2.91±0.02[e]	7.48±0.98
10	5.25	180	476.0±1.73	8.5±0.10[ab]	1365±4.00[d]	2.87±0.01[d]	7.57±0.80

[1)]Mean±SD.
[2)]Different letters (a-j) within the same column differ significantly ($p<0.05$).

Table 4. Analysis of predicted model equation for the physical properties of pan bread with ramie powder

Responses	Model	R-squared[1)]	F-value	Equation on terms of pseudo component
Weight	Quadratic	0.6056	1.12	$521.50+4.50A+10.08B-5.50AB-5.50A^2+0.25B^2$
Height	2FI	0.7630	6.44*	$9.20-1.22A-0.083B+0.92AB$
Volume	Quadratic	0.9817	43.03**	$1376.43-162.50A+195.00B+37.50AB+89.64A^2-72.86B^2$
Specific volume	Quadratic	0.9878	64.86***	$2.85-0.41A+0.37B+0.070AB+0.24A^2-0.11B^2$
Baking loss rate	Quadratic	0.8210	3.67	$7.30-1.17A+0.33B-1.14AB+0.25A^2+1.63B^2$

A: ramie power, B: water.
[1)]$0<R^2<1$, close to 1 means more significant.
*$p<0.05$, **$p<0.01$, ***$p<0.001$.

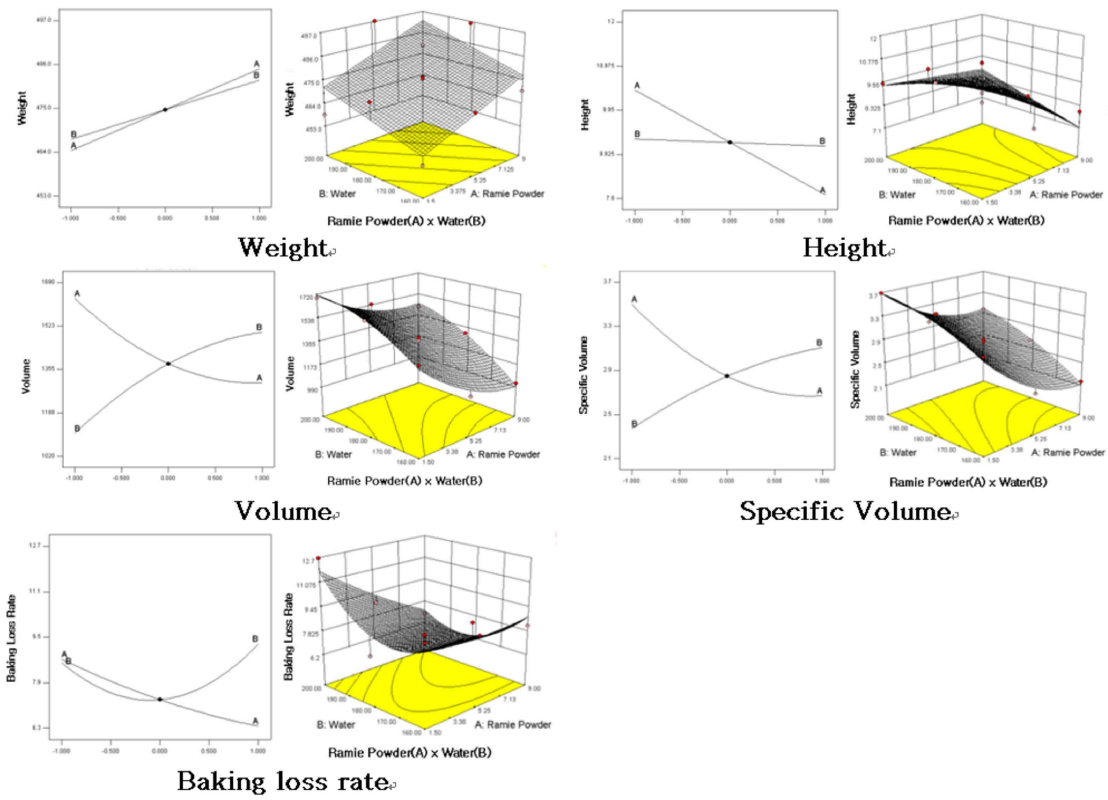

Fig. 1. Perturbation plot and response for surface for the effect of ramie powder (A), water (B) on physical properties of pan bread with ramie powder.

Table 5. Mechanical properties of pan bread with ramie powder

Sample No.	Ramie powder	Water	Crumb			Crust			Responses				
			L	a	b	L	a	b	Hardness	Springi-ness	Chewi-ness	Gummi-ness	Cohesivei-ess
1	1.50	160	66.19 ±0.16[j][1)]	-3.12 ±0.11[a]	22.58 ±0.04[d]	30.99 ±0.10	9.12 ±0.10[b]	18.47 ±0.08	333.600 ±16.30	1.885 ±0.10[c]	521.735 ±25.08	272.025 ±19.52	0.820 ±0.10
2	9.00	160	46.34 ±0.34[c]	-2.18 ±0.11[b]	27.04 ±0.12[i]	42.61 ±0.30	8.41 ±0.20[a]	23.59 ±0.21	470.500 ±23.30	1.010 ±0.02[a]	406.790 ±19.98	403.190 ±9.54	0.860 ±0.50
3	1.50	200	62.07 ±0.20[h]	-3.09 ±0.13[a]	19.70 ±0.20[b]	38.04 ±0.04	13.72 ±0.31[f]	20.01 ±1.01	280.933 ±20.25	2.140 ±0.10[d]	433.746 ±29.27	248.793 ±4.04	0.890 ±0.11
4	9.00	200	45.68 ±0.10[b]	-2.25 ±0.20[b]	24.80 ±0.35[f]	36.34 ±0.10	9.33 ±0.31[bc]	16.74 ±0.20	403.500 ±18.68	1.500 ±0.10[b]	534.960 ±10.15	356.640 ±9.46	0.880 ±0.12
5	1.50	180	64.04 ±0.33[i]	-3.16 ±0.12[a]	18.96 ±0.46[a]	38.03 ±0.09	14.32 ±0.09[g]	20.35 ±0.15	238.700 ±11.00	2.220 ±0.20[d]	463.450 ±30.04	208.460 ±7.90	0.870 ±0.12
6	9.00	180	41.48 ±0.02[a]	-1.96 ±0.10[c]	22.14 ±0.14[c]	33.29 ±0.10	9.54 ±0.09[c]	15.61 ±0.10	425.600 ±21.07	0.995 ±0.03[a]	370.135 ±13.23	371.795 ±15.87	0.875 ±0.10
7	5.25	160	55.91 ±0.15[g]	-3.08 ±0.10[a]	25.95 ±0.04[h]	42.01 ±0.10	11.82 ±0.40[de]	24.52 ±0.28	400.100 ±18.06	2.115 ±0.10[d]	735.800 ±35.00	348.480 ±7.80	0.870 ±0.12
8	5.25	200	51.35 ±0.20[d]	-3.17 ±0.20[a]	24.14 ±0.26[e]	40.10 ±0.08	11.97 ±0.20[e]	23.85 ±0.30	402.150 ±20.40	1.480 ±0.21[b]	473.885 ±19.59	344.100 ±12.68	0.855 ±0.06
9	5.25	180	52.26 ±0.11[f]	-2.99 ±0.10[a]	25.35 ±0.20[g]	37.72 ±0.20	11.60 ±0.15[d]	18.30 ±0.11	192.600 ±30.00	1.630 ±0.09[b]	373.325 ±34.64	167.680 ±5.96	0.875 ±0.02
10	5.25	180	51.91 ±0.09[e]	-3.03 ±0.07[a]	24.43 ±0.19[ef]	39.91 ±0.30	11.69 ±0.05[de]	21.43 ±0.20	196.000 ±21.07	2.140 ±0.04[d]	373.865 ±21.66	173.190 ±13.05	0.880 ±0.10

[1)]Mean±SD. Different letters (a-i) within the same column differ significantly ($p<0.05$).

Textural characteristics

The results of texture parameters (hardness, springiness, chewiness, gumminess, and cohesiveness) are shown in Table 5. The model equations and the coefficients of determination of the model equation are described in Table 6. The hardness and gumminess value increased

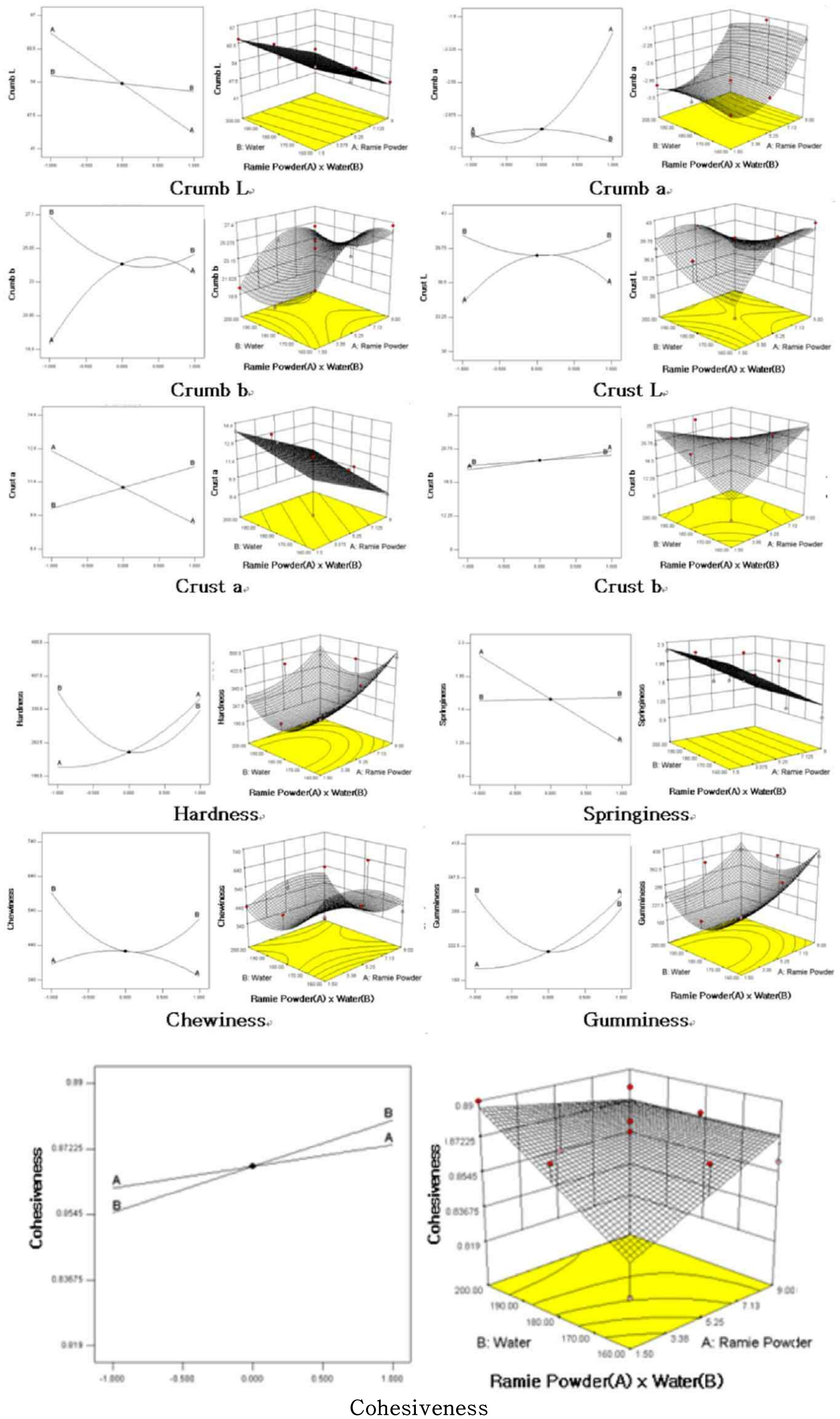

Fig. 2. Perturbation plot and response for the effect of ramie powder (A), water (B) on mechanical properties of pan bread with ramie powder.

Table 6. Analysis of predicted model equation for the mechanical properties of pan bread with ramie powder

Responses		Model	R-squared[1)]	F-value	Equation on terms of pseudo component
Crumb	L	Linear	0.9583	80.49***	53.72－9.80A－1.56B
	a	Quadratic	0.9828	45.75**	－3.01+0.50A－0.022B－0.025AB+0.46A^2－0.11B^2
	b	Quadratic	0.9039	7.52*	24.08+2.12A－1.16B+0.16AB－2.73A^2+1.77B^2
Crust	L	Quadratic	0.6987	1.86	39.07+0.86A－0.19B－3.33AB－3.67A^2+1.72B^2
	a	Linear	0.6041	5.34*	11.15－1.65A+0.95B
	b	2FI	0.4535	1.66	19.29+1.18A+0.67B－4.60AB
Hardness		Quadratic	0.8009	3.22	241.97+74.40A－19.60B－3.58AB+42.51A^2+111.49B^2
Springiness		Linear	0.6497	6.49*	1.71－0.46A+0.018B
Chewiness		Quadratic	0.5851	1.13	423.23－17.84A－36.96B+54.04AB－56.08A^2+131.97B^2
Gumminess		Quadratic	0.8059	3.32	212.10+67.06A－12.36B－5.83AB+36.37A^2+92.53B^2
Cohesiveness		2FI	0.5717	2.15	0.87+5.833A+0.013B－0.013AB

A: ramie power, B: water.
[1)]$0<R^2<1$, close to 1 means more significant.
*$p<0.05$, **$p<0.01$, ***$p<0.001$.

with an increase in ramie powder and was not significant. Similar results in white bread, which is made with sweet pumpkin powder (28) and Astragalus membranaceus powder, also reported that the different ingredients resulted in differences in hardness and gumminess (29). However, the springiness value decreased significantly with an increase in ramie powder ($p<0.05$). Jung (16) reported that the addition of mugwort powder had a very significant effect on white bread springiness. On the other hand, Jung et al. (28) reported that white bread made with sweet pumpkin powder exhibited increased springiness.

Sensory evaluation

The sensory values of color, flavor, appearance, moistness, and overall quality were in the ranges of 3.9～6.3, 3.0～5.0, 3.4～5.4, 2.9～6.1, and 3.2～6.5, respectively (Table 7). The model equations and coefficients of determination of the model equations are given in Table 8. The ramie powder white bread showed very significant results for color and moistness ($p<0.001$). Shown in Fig. 3, flavor decreased with ramie powder more added to ramie ($p<0.05$). A greater addition of ramie powder decreased the preference in appearance and moistness. But water had little influence on the appearance ($p<0.01$) and moistness. In overall quality, it appeared that as

Table 7. Sensory evaluation of pan bread with ramie powder

Sample No.	Ramie powder	Water	Sensory evaluation				
			Color	Flavor	Appearance	Moistness	Overall quality
1	1.50	160	4.5±1.58[abc1)]	4.5±0.85[c]	5.0±1.49[d]	5.4±1.71[de]	5.7±0.67[bcd]
2	9.00	160	4.2±1.32[ab]	3.0±0.67[a]	3.5±0.85[ab]	2.9±0.74[a]	3.2±0.79[a]
3	1.50	200	4.7±0.06[abc]	4.7±0.95[c]	5.4±1.07[d]	5.8±0.79[e]	5.6±0.70[bc]
4	9.00	200	3.9±0.88[a]	3.4±1.26[ab]	3.4±1.51[a]	3.4±1.26[abc]	3.2±1.40[a]
5	1.50	180	5.2±1.14[bcd]	4.7±1.16[c]	4.6±0.84[bcd]	6.1±0.99[e]	5.6±0.84[bc]
6	9.00	180	4.7±1.25[abc]	2.7±0.48[a]	3.8±0.63[abc]	3.1±0.74[ab]	3.2±0.63[a]
7	5.25	160	5.5±0.85[cde]	4.1±0.99[bc]	4.4±1.26[abcd]	4.5±1.35[cd]	4.9±0.74[b]
8	5.25	200	5.5±0.85[cde]	4.7±0.82[c]	4.5±0.85[abcd]	4.1±0.99[bc]	6.0±1.05[cd]
9	5.25	180	6.3±0.48[e]	4.7±1.34[c]	4.8±1.48[cd]	4.3±1.49[cd]	6.5±0.71[d]
10	5.25	180	6.1±0.88[de]	5.0±0.94[c]	4.6±1.26[bcd]	4.5±1.08[cd]	6.3±0.48[cd]

[1)]Mean±SD. Different letter (a-e) within the same column differ significantly ($p<0.05$).

Table 8. Analysis of predicted model equation for the sensory quality characteristics of pan bread with ramie powder

Responses	Model	R-squared[1)]	F-value	Equation on terms of pseudo component
Color	Quadratic	0.9956	181.96***	6.18－0.27A－0.017B－0.13AB－1.21A^2－0.66B^2
Flavor	Quadratic	0.9278	10.28*	4.66－0.80A+0.20B+0.050AB－0.78A^2－0.079B^2
Appearance	Linear	0.8223	16.20**	4.40－0.72A+0.067B
Moistness	Linear	0.9873	78.49***	4.41－1.32A+0.083B
Overall quality	Quadratic	0.9367	11.84*	6.12－1.22A+0.17B+0.025AB－1.44A^2－0.39B^2

A: ramie power, B: water.
[1)]$0<R^2<1$, close to 1 means more significant.
*$p<0.05$, **$p<0.01$, ***$p<0.001$.

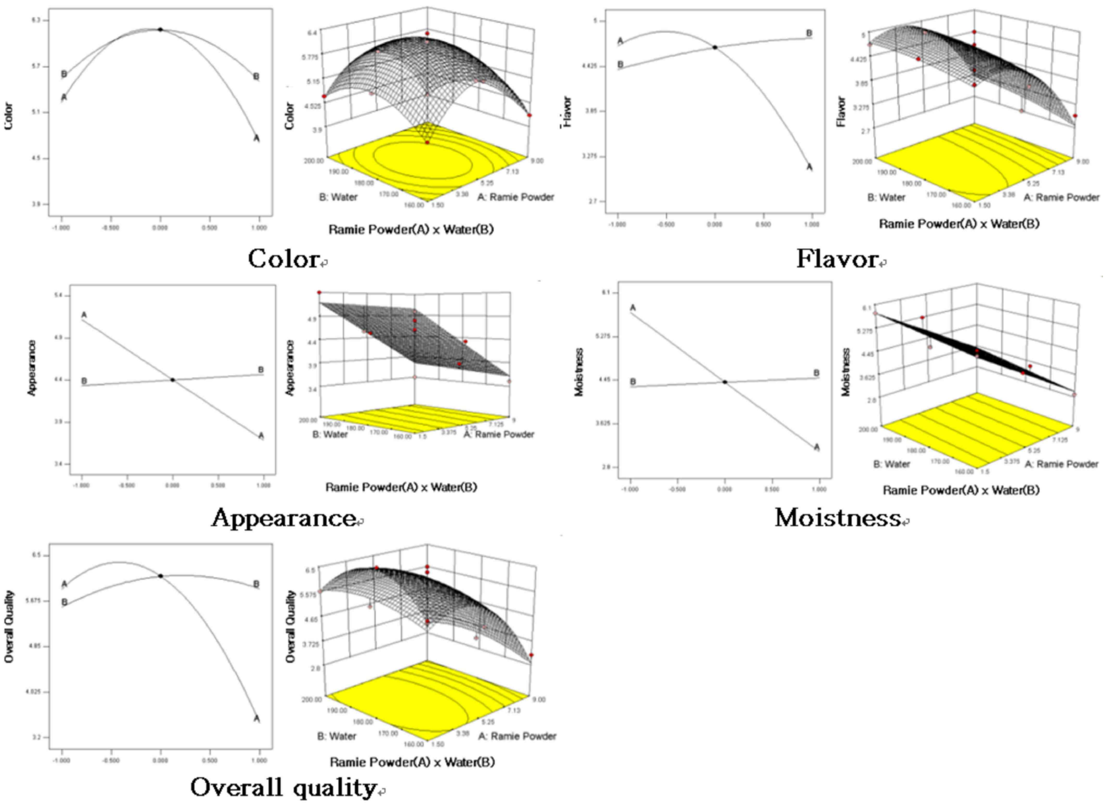

Fig. 3. Perturbation plot and response for the effect of ramie powder (A), water (B) on the sensory characteristics (overall quality) of pan bread with ramie powder.

more ramie powder increased, the preference in overall quality decreased ($p<0.05$). An increased addition of ramie powder contributed to a decreased overall quality of the final product; additional water showed little influence on the overall quality of white bread. A similar result on the overall quality of white bread made with mugwort (16), persimmon leaves (14), green tea (15), and *Nelumbo nucifera* G. tea power (11) was found.

Optimization

The optimal amounts of pan white bread with ramie powder and water 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 and graphical optimization (Fig. 4). The optimal point with the highest desirablility was deducted through point prediction, and the predicted optimal values were 2.76 g (0.92%) of ramie powder and 184.7 mL of water. Another bread study with mugwort (16) and green tea power (15) indicated 2.5% of overall acceptability. According to Lee et al. (8), the critical values from the sensory characteristics showed that 27 g

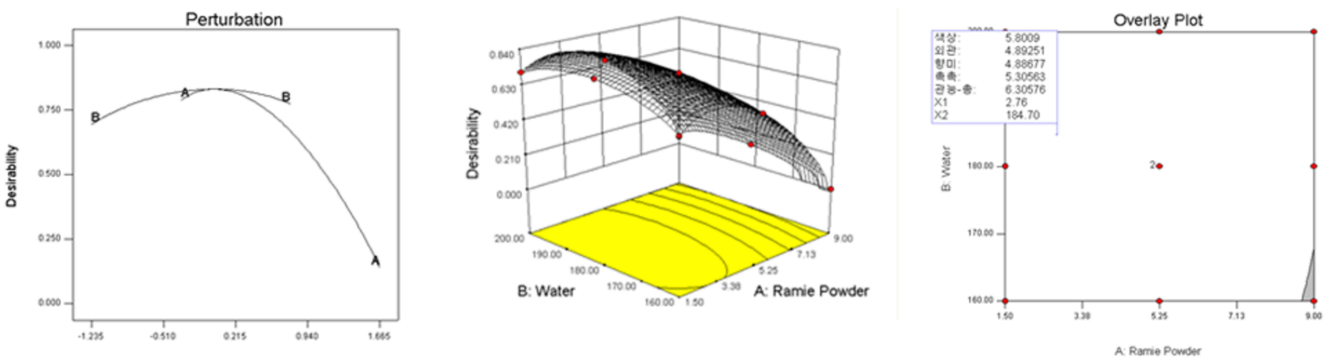

Fig. 4. Perturbation plot, the response surface plot and overlay plot for optimization mixture on desirability of pan bread with ramie powder.

of dukeum ramie power was optimal for a muffin.

DPPH radical scavenging activity

Free radical scavenging properties of optimized pan bread with ramie powder and white pan bread from different irradiation are presented in Table 9. Optimized pan bread with ramie power (0.92%) had higher antioxidant effects than white pan bread (0%). Lee et al. (1) reported that DPPH radical, hydroxyl radical, and superoxide radical scavenging of ramie leaf extracts were 688, 424, and 596 μg/mL, respectively and ramie leave had antioxidant effects equivalent to the plants used for medicinal purposes. According to Park (6) the antioxidant effects of sulgidduk with ramie powder showed higher antioxidant activity than those of the control group of vitamin C and BHT addition. But irradiated pan bread with an increase in storage days showed lower scavenging ability on DPPH radicals. A similar result on the radiation effect of the irradiated green tea leaf extract was found (30). However, Park et al. (31) reported that the changes of radical scavenging activity of irradiated green tea were negligible.

From these results, ramie power showed a higher amount of antioxidant activity and it was higher than non-addition with non-irradiation.

Bacterial analysis during storage

Table 10 represents the results of changes in a total cell count of the predicted optimal values of white bread with ramie powder and control after gamma irradiation during storage. White pan bread with ramie powder had fewer total cells than white pan bread. The results of non-irradiated jeolpyun with ramie leaf had results similar to ours (5). Until day seven, no germs were observed

Table 9. Effect of DPPH radical scavenging activity of optimized pan bread with ramie powder and white pan bread during storage

Irradiation dose		Storage period (days)										
		0	1	2	3	4	5	6	7	8	9	10
WB[1)]	Non	83.74 ±2.65^{e}[2)]	76.73 ±3.16^{d}	76.70 ±8.69^{bc}	71.72 ±4.58^{c}	67.16 ±0.39^{c}	66.88 ±1.95^{a}	65.26 ±2.76^{c}	63.92 ±2.88^{b}	59.59 ±5.95^{b}	57.66 ±3.40^{b}	47.10 ±4.32^{b}
	10 kGy	47.08 ±0.64^{c}	33.55 ±1.51^{c}	28.42 ±3.44^{a}	28.35 ±2.86^{b}	25.64 ±2.32^{b}	28.34 ±4.41^{b}	23.06 ±4.59^{b}	17.18 ±2.37^{a}	16.09 ±0.51^{a}	13.65 ±1.42^{a}	13.12 ±2.07^{a}
	15 kGy	41.97 ±1.47^{b}	29.54 ±1.42^{b}	25.97 ±4.33^{a}	21.18 ±1.48^{a}	21.02 ±1.08^{a}	23.17 ±1.26^{c}	16.59 ±4.76^{a}	15.04 ±1.59^{a}	15.24 ±2.01^{a}	12.94 ±1.36^{a}	11.05 ±1.93^{a}
	20 kGy	35.41 ±1.34^{a}	21.65 ±0.94^{a}	21.43 ±1.54^{a}	20.80 ±0.66^{a}	18.68 ±1.02^{a}	18.36 ±0.56^{c}	15.98 ±1.46^{a}	14.35 ±1.00^{a}	13.98 ±0.57^{a}	12.42 ±3.56^{a}	9.15 ±0.57^{a}
RB	Non	97.53 ±1.97^{f}	90.98 ±2.00^{f}	89.61 ±2.85^{d}	89.32 ±1.17^{e}	88.82 ±2.09^{g}	87.83 ±1.22^{d}	84.05 ±3.41^{e}	83.82 ±1.07^{d}	81.71 ±1.29^{c}	79.87 ±7.01^{e}	75.04 ±9.27^{d}
	10 kGy	86.14 ±1.99^{e}	87.31 ±1.92^{f}	85.20 ±2.89^{cd}	84.76 ±3.92^{de}	84.46 ±2.46^{f}	82.13 ±5.92^{d}	81.57 ±2.08^{de}	79.07 ±0.74^{cd}	79.01 ±2.17^{c}	77.79 ±2.18^{e}	66.40 ±8.04^{cd}
	15 kGy	83.23 ±1.79^{e}	82.22 ±3.14^{e}	80.49 ±3.08^{bc}	80.18 ±1.27^{d}	77.32 ±2.48^{e}	77.19 ±1.38^{e}	76.52 ±3.31^{d}	75.66 ±4.43^{c}	74.91 ±2.17^{c}	70.88 ±1.97^{d}	63.00 ±0.61^{c}
	20 kGy	76.68 ±1.60^{d}	74.21 ±1.77^{d}	73.33 ±4.52^{b}	73.14 ±3.90^{c}	72.30 ±2.49^{d}	71.48 ±2.75^{a}	70.01 ±0.71^{c}	68.81 ±5.45^{b}	67.09 ±2.58^{bc}	63.97 ±2.91^{c}	55.56 ±8.60^{bc}

[1)]WB: white pan bread, RB: optimized pan bread with ramie powder.
[2)]Mean±SD. Different letters (a-g) within a column are significantly different ($p<0.001$, n=3).

Table 10. Effect of irradiation on the growth (log CFU) of total plate counts of optimized pan bread with ramie powder and white pan bread during storage

Pan bread	Irradiation dose	Total plate counts (log CFU)					
		0 day	1 day	3 days	5 days	7 days	9 days
WB[1)]	Non	ND[2)]	ND	4.31±0.31[3)]	5.83±0.18	6.10±0.37	6.26±0.23
	10 kGy	ND	ND	ND	ND	ND	4.39±0.76
	15 kGy	ND	ND	ND	ND	ND	3.65±0.23
	20 kGy	ND	ND	ND	ND	ND	ND
RB	Non	ND	ND	4.04±0.12	5.42±0.41	5.75±0.21	5.82±0.04
	10 kGy	ND	ND	ND	ND	ND	ND
	15 kGy	ND	ND	ND	ND	ND	ND
	20 kGy	ND	ND	ND	ND	ND	ND

[1)]WB: white pan bread, RB: optimized pan bread with ramie powder.
[2)]ND: Not determined.
[3)]Mean±SD.

on non-irradiated pan bread. A similar result on antimicrobial efficacy of the irradiated leafy green vegetables was found (32). After three days of storage, non-irradiated optimized pan bread with ramie powder and white pan bread showed cell counts in the range of 4.04 ±0.12 and 4.31±0.31, respectively and after nine days of storage, counts of 5.82±0.04, 6.26±0.23, respectively. According to Kim et al. (33), the irradiated sauce saw a reduction in total aerobic bacterial cell counts below a detection limit. Also, the results of sliced Roma tomatoes were similar to ours (34).

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