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

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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 teek (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 intestinalis (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.
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 Scientific Co., Bucheon, Korea). Fat contents were determined by Soxhlet method with a solvent extraction system (Soxtect ®Avanti 2050 Auto System, Foss Tecator AB, Höganäs, Sweden) and protein was determined by Kjeldahl method with an automatic Kjeldahl nitrogen analyzer (Kjeltex ®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 planned Central Composite design of response surface methodology. As independent variables, the two factors chosen were Ramie powder 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:

Baking loss = \(\frac{\text{DW} - \text{BW}}{\text{DW}}\) × 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 (Colorimeter 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|        |             |             |      |
| 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.

\[ D = \left( \prod_{i=1}^{n} d_i \right)^{\frac{1}{n}} \]

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 60Co 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.

**DPH radical scavenging activity during storage**

The DPH 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 = \( \frac{1}{100} \times \left( 1 - \text{absorbance value of testing solution/absorbance value of control solution} \right) \)

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 mugwort 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 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 | Weight (g) | Height (cm) | Volume (cc) | Specific volume (cm³/g) | Baking loss rate (%) |
|-----|--------------|-------|------------|-------------|-------------|------------------------|---------------------|
| 1   | 1.50         | 160   | 453.0 ± 2.64<sup>a</sup> | 12.0 ± 0.50<sup>ab</sup> | 1425 ± 5.56<sup>a</sup> | 3.15 ± 0.02<sup>b</sup> | 9.40 ± 1.47<sup>b</sup> |
| 2   | 9.00         | 160   | 470.0 ± 6.24<sup>a</sup> | 8.0 ± 0.10<sup>b</sup> | 1020 ± 1.32<sup>a</sup> | 2.17 ± 0.03<sup>b</sup> | 8.20 ± 1.92<sup>b</sup> |
| 3   | 1.50         | 200   | 458.5 ± 3.04<sup>b</sup> | 9.5 ± 0.30<sup>ab</sup> | 1690 ± 8.66<sup>b</sup> | 3.69 ± 0.01<sup>b</sup> | 12.67 ± 1.40<sup>b</sup> |
| 4   | 9.00         | 200   | 479.5 ± 5.86<sup>b</sup> | 9.2 ± 0.20<sup>d</sup> | 1435 ± 2.64<sup>b</sup> | 2.99 ± 0.00<sup>d</sup> | 6.89 ± 0.41<sup>d</sup> |
| 5   | 1.50         | 180   | 472.5 ± 2.78<sup>b</sup> | 11.0 ± 1.00<sup>d</sup> | 1625 ± 4.00<sup>b</sup> | 3.44 ± 0.02<sup>d</sup> | 7.35 ± 0.91<sup>d</sup> |
| 6   | 9.00         | 180   | 496.0 ± 6.00<sup>b</sup> | 8.0 ± 0.20<sup>b</sup> | 1310 ± 3.00<sup>b</sup> | 2.64 ± 0.03<sup>b</sup> | 7.29 ± 0.98<sup>b</sup> |
| 7   | 5.25         | 160   | 467.5 ± 1.32<sup>b</sup> | 8.0 ± 0.10<sup>b</sup> | 1060 ± 1.73<sup>b</sup> | 2.27 ± 0.01<sup>b</sup> | 8.69 ± 0.58<sup>b</sup> |
| 8   | 5.25         | 200   | 497.0 ± 6.24<sup>b</sup> | 8.8 ± 0.20<sup>b</sup> | 1550 ± 2.00<sup>b</sup> | 3.12 ± 0.03<sup>b</sup> | 8.72 ± 1.25<sup>b</sup> |
| 9   | 5.25         | 180   | 476.5 ± 2.29<sup>b</sup> | 9.0 ± 0.20<sup>b</sup> | 1385 ± 2.78<sup>b</sup> | 2.91 ± 0.02<sup>b</sup> | 7.48 ± 0.98<sup>b</sup> |
| 10  | 5.25         | 180   | 476.0 ± 1.73<sup>b</sup> | 8.5 ± 0.10<sup>b</sup> | 1365 ± 4.00<sup>b</sup> | 2.87 ± 0.01<sup>d</sup> | 7.57 ± 0.80<sup>d</sup> |

<sup>a</sup>Mean ± SD.

<sup>b</sup>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<sup>1</sup> | F-value | Equation on terms of pseudo component |
|--------------------|--------|------------------------|---------|--------------------------------------|
| Weight             | Quadratic | 0.6056 | 1.12 | 521.50+4.50A+10.08B−5.50AB−5.50A<sup>2</sup>+0.25B<sup>2</sup> |
| Height             | 2FI    | 0.7630 | 6.44 | 9.20−1.22A−0.083B+0.92AB |
| Volume             | Quadratic | 0.9817 | 43.03<sup>**</sup> | 1376.43−162.50A+195.00B+37.50AB+89.64A<sup>2</sup>−72.86B<sup>2</sup> |
| Specific volume    | Quadratic | 0.9878 | 64.86<sup>**</sup> | 2.85−0.41A+0.37B+0.070AB+0.24A<sup>2</sup>−0.11B<sup>2</sup> |
| Baking loss rate   | Quadratic | 0.8210 | 3.67 | 7.30−1.17A+0.33B−1.14AB+0.25A<sup>2</sup>+1.63B<sup>2</sup> |

A: ramie powder, B: water.

<sup>1</sup>p<0.05, <sup>**</sup>p<0.01, <sup>***</sup>p<0.001.
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**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         |
| 1          | 1.50         | 160   | 66.19 | -3.12 | 23.58     |
| 2          | 9.00         | 160   | 46.34 | -2.18 | 27.04     |
| 3          | 1.50         | 200   | 62.07 | -3.09 | 19.70     |
| 4          | 9.00         | 200   | 45.68 | -2.25 | 24.80     |
| 5          | 1.50         | 180   | 64.04 | -3.16 | 18.96     |
| 6          | 9.00         | 180   | 41.48 | -1.96 | 22.14     |
| 7          | 5.25         | 160   | 55.91 | -3.08 | 25.95     |
| 8          | 5.25         | 200   | 51.35 | -3.17 | 24.14     |
| 9          | 5.25         | 180   | 52.26 | -2.99 | 25.35     |
| 10         | 5.25         | 180   | 51.91 | -3.03 | 24.43     |

**Table 5.** Mechanical properties of pan bread with ramie powder

| Sample No. | Ramie powder | Water | Crumb | Crust | Responses |
|------------|--------------|-------|-------|-------|-----------|
| L          | a            | b     | L     | a     | b         |
| 1          | 1.50         | 160   | 66.19 | -3.12 | 23.58     |
| 2          | 9.00         | 160   | 46.34 | -2.18 | 27.04     |
| 3          | 1.50         | 200   | 62.07 | -3.09 | 19.70     |
| 4          | 9.00         | 200   | 45.68 | -2.25 | 24.80     |
| 5          | 1.50         | 180   | 64.04 | -3.16 | 18.96     |
| 6          | 9.00         | 180   | 41.48 | -1.96 | 22.14     |
| 7          | 5.25         | 160   | 55.91 | -3.08 | 25.95     |
| 8          | 5.25         | 200   | 51.35 | -3.17 | 24.14     |
| 9          | 5.25         | 180   | 52.26 | -2.99 | 25.35     |
| 10         | 5.25         | 180   | 51.91 | -3.03 | 24.43     |

**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.
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.

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

| Responses | Model   | R-squared | F-value      | Equation on terms of pseudo component |
|-----------|---------|-----------|--------------|---------------------------------------|
| Crumb     | Linear  | 0.9583    | 80.49***     | 53.72 − 9.80A − 1.56B                  |
| L         | Quadratic a | 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     | Linear  | 0.6987    | 1.86         | 39.07+0.86A−0.19B−3.33AB−3.67A^2+1.72B^2 |
| L         | Quadratic a | 0.6014 | 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 powder, B: water.

**1**p<0.05, **2**p<0.01, ***p<0.001.

### Table 7. Sensory evaluation of pan bread with ramie powder

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

**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 | 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+0.05AB−0.78A^2−0.07B^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 powder, B: water.

**1**p<0.05, **2**p<0.01, ***p<0.001.

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
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 desirability 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
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.

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**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        |
| Non              | 83.74     | 76.73     | 76.70     | 71.72     | 67.16     | 66.88     | 65.26     | 63.92     | 59.59     | 57.66     | 47.10     |
|                  | ±2.65c    | ±3.16d    | ±8.69b    | ±4.58c    | ±0.39c    | ±1.95a    | ±2.76c    | ±2.88b    | ±5.95b    | ±3.40b    | ±4.32b    |
| WB (1)           | 10 kGy    | 47.08     | 33.55     | 28.42     | 28.35     | 25.64     | 28.34     | 23.06     | 17.18     | 16.09     | 13.65     |
|                  | ±0.64c    | ±1.51c    | ±3.44b    | ±2.86b    | ±2.32b    | ±4.41b    | ±4.59b    | ±2.37c    | ±0.51a    | ±1.42c    | ±2.07c    |
|                  | 15 kGy    | 41.97     | 29.54     | 25.97     | 21.18     | 21.02     | 23.17     | 16.59     | 15.04     | 15.24     | 12.94     |
|                  | ±1.47b    | ±1.42b    | ±4.33a    | ±1.48a    | ±1.08a    | ±1.26c    | ±4.76a    | ±1.59c    | ±2.01a    | ±1.36c    | ±1.93c    |
|                  | 20 kGy    | 35.41     | 21.65     | 21.43     | 20.80     | 18.68     | 18.36     | 15.98     | 14.35     | 13.98     | 12.42     |
|                  | ±1.34a    | ±0.94a    | ±1.54a    | ±0.66a    | ±1.02a    | ±0.56c    | ±1.46a    | ±1.00c    | ±0.57a    | ±3.56a    | ±0.57a    |

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 | 0 day | 1 day | 3 days | 5 days | 7 days | 9 days |
|-----------|------------------|-------|-------|--------|--------|--------|--------|
| WB (1)    | Non              | ND    | ND    | 4.31±0.31 | 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).

REFERENCES

1. Lee YR, Nho JW, Hwang IG, Kim WJ, Lee YJ, Jeong HS. 2009. Chemical composition and antioxidant activity of ramie leaf (Boehmiera nivea L.). Food Sci Biotechnol 18: 1096-1099.

2. Lee SJ (Li Shihchen). 1578. Bonchokangmok (Pents’ao kangmu). China.

3. Kim IS. 2008. Antibacterial, antioxidant activities and cell viability against cancer of Adenophora remotiflora leaves. PhD Dissertation. University of Wonkwang, Jeonbuk, Korea.

4. Kim SI, An MJ, Han YS, Pyeun JH. 1993. Sensory and instrumental texture properties of rice cakes according to the addition of songpy (pine tree endodermis) or mosipul (China grass leaves). J Korean Soc Food Nutr 22: 603-613.

5. Yoon SJ, Jang MS. 2006. Characteristics of quality in jeolpyun with different amounts of ramie. Korean J Food Cookery Sci 23: 636-641.

6. Park SS. 2010. Antioxidative activity and quality characteristics of Sulgidduk added ramie leaf powder. MS Thesis. SooKmyung Woman’s University, Seoul, Korea.

7. Lee SR, Kim SJ, Kim GH. 2001. Quality characteristics of Adenophora remotiflora for increasing the value as a food resource. Annals of Plant Resources Research 7: 117-124.

8. Lee YJ, Woo KS, Jeong HS, Kim WJ. 2010. Quality characteristics of muffins with added Dukeun (pan-fried) ramie leaf (Boehmiera nivea) powder using response surface methodology. Korean J Food Culture 25: 810-819.

9. Paik JE, Bae HJ, Joo NM, Lee SJ, Jung HA, Ahn EM. 2010. The quality characteristics of cookies with added Boehmiera nivea. Korean J Food & Nutr 23: 446-452.

10. Shin SR, Shin S, Shin GM. 2008. Quality characteristics of white pan bread by pomegranate with added pomegranate powder. Korean J Food & Nutr 4: 492-498.

11. Kim YS, Kim MY, Shun SS. 2008. Quality characteristics of domestic wheat white bread with substituted Nelumbo nucifera G. tea powder. Korean J Food & Nutr 21: 448-456.

12. Lim EJ, Lee YH, Huh CO, Kwon SH, Kim JY, Han YB. 2007. Rheological properties of bread dough added with Enteromorpha intestinalis. Korean J Food Sci Technol 39: 652-657.

13. Shin JW, Shin GM. 2008. Rheological properties of dough with added Corni fructus flour. Korean J Food Preserv 15: 390-395.

14. Kang WW, Kim GY, Kim KJ, Oh SL. 2000. Quality characteristics of the bread added persimmon leaves powder. Korean J Soc Food 16: 336-341.

15. Im JG, Kim YH. 1999. Effect of green tea addition on the quality of white bread. Korean J Soc Food Sci 15: 395-400.

16. Jung IC. 2006. Rheological properties and sensory characteristics of white bread with added mugwort powder. J East Asian Soc Dietary Life 16: 332-343.

17. Han JI, Kim KY, Kim YM, Ahn CB, Kim DW, Park KT, Chun SS. 2007. Quality characteristics of white bread with red ginseng marc powder. J East Asian Soc Dietary Life 17: 242-249.

18. Kim HJ, Feng H, Toshkov SA, Fan X. 2005. Effect of sequential treatment of warm water dip and low-dose gamma irradiation on the quality of fresh-cut green onions. J Food Sci 70: 179-185.

19. AOAC. 1990. Official methods of analysis. 15th ed. Association of Official Analytical Chemists, Washington, DC, USA.

20. Joo NM, Lee SM, Jeong HS. 2009. Optimization of jelly made with Rubus coreanus (Bokbunja) using response surface methodology. J Food Sci Nutr 14: 148-155.

21. Pyler EJ. 1979. Physical and chemical test method, baking science and technology. Sociland pup Co., Kansas, MO, USA. p 891.

22. Lee JH, Kwak EJ, Kim JS, Lee KS, Lee YS. 2007. A study on quality characteristics of sourdough breads with addition of red eye at rice. J Korean Soc Food Sci Nutr 36: 789-793.

23. Lee JW, Yoon YH. 2010. Use of irradiation in food processing as green technology. Food Science and Industry 43: 53-63.

24. Park JG, Joo JH, Byun MW, Jeon YE, Kang JI, Hwang HJ, Lee JW. 2011. Subacute toxicity study of 40 kGy irradiated ready-to-eat bulgogi. J Food Sci Nutr 16: 83-88.

25. Choi HY, Oh SY, Lee YS. 2009. Antioxidant activity and quality characteristics of perilla leaves (Perilla frutescens var. japonica HARA) cookies. Korean J Food Cookery Sci 25: 521-530.

26. Lee JR, Han YJ, Lee TW, Song YM, Jin SK, Kim IS, Hah K, Kwak SJ. 2002. Physico-chemical and sensory properties of emulsified sausages containing mulberry and persimmon leaf powder. Korean J Food Sci Anim Resour 22: 330-336.

27. Bae JY, Park LY, Lee SH. 2008. Effect of Salicornia herbacea L. powder on the quality characteristics of bread. J Korean Soc Food Sci Nutr 37: 1196-1201.

28. Jung SY, Seog EJ, Lee JH. 2006. Quality bread as influenced by sweet pumpkin powder. J Food Sci Nutr 11: 339-343.

29. Min SH, Lee BR. 2008. Effect of Astragalus membranaceus powder on yeast bread baking quality. Korean J Foodculture 23: 232-234.

30. Jo CR, Byun MW. 2003. Effect of storage temperature and antioxidant additives on the color and physiological activity of gamma irradiated green tea leaf extract. Nutraceuticals and Food 8: 113-218.

31. Park JH, Lee JM, Lee SC. 2006. Effect of electron-beam irradiation on the characteristics of green tea (Camellia sinensis L). J Korean Soc Food Sci Nutr 35: 774-779.

32. Niemira BA, Cooke PH. 2010. Escherichia coli O157:H7 biofilm formation on romaine lettuce and spinach leaf surfaces reduces efficacy of irradiation and sodium hypochlorite washes. J Food Sci 75: 270-277.
33. Kim YS, Kim HJ, Yoon YH, Shin MG, Kim CJ, Sin MH, Lee JW. 2010. Antimicrobial effects of retort and gamma irradiation on bacterial populations in spicy chicken sauce. *Korean J Food Sci Ani Resour* 30: 141-147.

34. Niemira BA. 2011. Influence of refrigerated storage time on efficacy of irradiation to reduce *Salmonella* on sliced roma tomatoes. *J Food Prot* 74: 990-993.

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