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Analyzing Manufacturing Process of *Prunus mume*-Added Vinegared Red Pepper Paste with Respect to Physicochemical Properties

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Abstract: Response Surface Methodology (RSM) was used for analyzing the manufacturing process of *Prunus mume*-added vinegared red pepper paste with respect to physicochemical quality properties. Experiments were carried out according to a central composite design, selecting amount of *kochujang*, amount of *maesil* extract and type of sugar in the mixture as independent variables and pH, titratable acidity, moisture content, soluble solids content and CIE color parameters (L^*-, a^*- and b^*-values) as response variables. The polynomial models developed by RSM were highly effective to describe the relationships between the studied factors and the responses. The estimated response surfaces confirm that the amount of *maesil* extract has a negative and positive effect on pH and titratable acidity, respectively. The response surfaces also show that the amount of *kochujang* and *maesil* extract have a negative effect on moisture content. Soluble solids content increased significantly with increasing amount of *kochujang* in the sample but moderate increase due to *maesil* extract. L^*-, a^*- and b^*-values ranged from 27.86-32.43, 14.52-21.42 and 11.39-18.61, respectively. The amount of *maesil* extract has a negative effect on L^*-, a^*- and b^*-values.

Key words: Vinegared red pepper paste, *chokochujang*, *Prunus mume*, *maesil*, physicochemical, RSM

INTRODUCTION

Vinegared red pepper paste (*chokochujang*) is usually made with *kochujang*, sugar, garlic and vinegar to produce mixed flavor of hot, sweetness as well as sourness. Its taste and flavor are mostly influenced by the mixing ratio of each ingredient. It has been usually made by experience but to produce uniform and improved high quality (taste, flavor, color, texture and so on) product, it is of importance to analyze the manufacturing process with respect to physicochemical properties.

Prunus mume (*maesil*) is a species of Asian plum in the family of Rasaceae. The tree originates from China, but it has also been grown in Korea, Taiwan and Japan since ancient times (Lee *et al*., 2004) The fruits are generally black in color and are believed to be effective against parasite, as well as in stopping ulcers and promoting a strong digestive system and heart (Lee *et al*., 2002; 2004) *Prunus mume* extracts showed remarkable antimicrobial effects against the wide spectrum of putrefactive and food spoilage microorganisms and also an anticancer activity (Lee, 1998; Bae *et al*., 2000; Lim, 1999).

The purpose of this study was to examine the physicochemical quality changes of *chokochujang* as influenced by amount of *kochujang*, *maesil* extract and type of sugar in the manufacturing processing using response surface methodology.

MATERIALS AND METHODS

Kochujang premixture was obtained from Poorun Foods Co., Ltd., which was prepared by blending wheat powder (22%), wheat grain (20%), salt (10.5%) and purified water (47.5%). Wheat flour was first steamed with pressure after spraying the warm water and blended with ground wheat grain (inoculated with 0.05% spore suspension of *Aspergillus oryzae* starter and incubated at 35-40°C for 48-52 h) in uniform sizes and salt, then stored in a fermentation tank for 1 month. *Maesil* extract was purchased from Saehan Maesil Farm (Miryang, Gyeongnam, Korea) and corn syrup (100% corn starch, TS Co., Ltd., Incheon, Korea), red pepper powder, mixed condiments (contained 38% red pepper powder, 15% salt, 7% garlic and 4% onion) and spirits (Haitai and Company, Seoul, Korea) were also obtained from Poorun Foods Co., Ltd. The soluble solid content and pH of *maesil* extract were 68.3°Brix and 2.8, respectively. Vinegar was procured from a local market.

***Chokochujang* preparation:** *Kochujang* was first prepared using the commercially manufacturing practice by Poorun Foods Co., Ltd. Aged *kochujang* premixture and 30% corn syrup were pasteurized at 70°C while blending 8% mixed condiments, 8.6% red pepper powder, and 3% spirits. The mixtures were then cooled down to 40-45°C, placed in a pot and aged for 100 days at room temperature (23-24°C) before use. *Chokochujang* was prepared by mixing *kochujang* (105-195 g), *maesil* extract (0-30 g), sugar (black, brown and white), garlic (15 g) and vinegar (60 g).

pH and titratable acidity measurement: Five grams of *chokochujang* were blended with distilled water (sample:water = 1: 9, w w^{-1}) for 1 min. The pH of the sample was determined using a pH meter (Model 340, Mettler Delta Co., Halstead, UK) at room temperature. Same sample was used to measure titratable acidity, amount of 0.1 N NaOH solution to titrate the sample beyond pH = 8.3. All measurements were done in triplicate.

Moisture and soluble solids content measurement: The moisture content was determined using convection oven at 105°C overnight. Soluble solids content of the diluted *chokochujang* samples was determined at room temperature with a refractometer (PR-301, Atago Co., Tokyo, Japan). All measurements were done in triplicate.

Color measurement: Color was measured using a Chromameter (model CR-200, Minolta Co., Osaka, Japan) calibrated with a calibration plate using Y = 94.2, x = 0.3131 and y = 0.3201. Color was recorded using the *CIE-L*a*b** uniform color space, where *L** indicates lightness, *a** indicates chromaticity on a green (-) to red (+) axis and *b** chromaticity on a blue (-) to yellow (+) axis. All measurements were done in triplicate.

Experimental design: Response Surface Methodology (RSM) was employed to investigate the *chokochujang* manufacturing process. A three-variable, three-level central composite design was employed where the independent variables were the amount of *kochujang* (105-195 g), *maesil* extract (0-30 g) and type of sugar used (black, brown and white). The experimental design in the coded and actual levels of variables is shown in Table 1. The response functions (*Y*) were pH, titratable acidity, soluble solids and moisture content and color characteristics (*L**-, *a**- and *b**-values).

The complete designs consisted of 16 combinations (including two replicates of the center point) and were carried out in random order (Table 2). A quadratic polynomial regression model was assumed for prediction purpose of the responses (Y). The model proposed was:

Table 1: Independent variables and their levels in central composite design

Independent variables	Unit	Symbol	Coded levels -1	0	1
Kochujang	(g)	x_1	105	150	195
Maesil extract	(g)	x_2	0	15	30
Sugar	-	x_3	1 (White)	2 (Brown)	3(Black)

$$Y = \beta_0 + \sum_{i=1}^{3} \beta_i x_i + \sum_{i \neq j=1}^{3} \beta_{ij} x_i x_j + \sum_{i=1}^{3} \beta_{ii} x_i^2$$

Where, Y is the response variable, β_0 the intercept, β_i the coefficients for the linear, β_{ii} the coefficients for the quadratic effect, β_{ij} the coefficients for the interaction effect. The above equation was solved using SAS package to estimate the responses of the dependent variables and the contour plots were generated.

RESULTS AND DISCUSSION

Table 3 presents the regression coefficients, R^2 and probability values for seven dependent variables for *chokochujang*. Analysis of variance for the seven response variables indicated that the response surface models developed for all the response variables were adequate. The R^2 values, is defined as the ratio of the explained variation to the total variation (Haber and Runyon, 1977), for these response variables ranged from 0.8857-0.9977 indicating that a high proportion of variability was explained by the data. It has been suggested that model with R^2 greater than 0.8 indicate a good fit (Joglekan and May, 1987).

Minimum pH (3.50) was found when *chokochujang* was made with 195 g of *kochujang*, with black sugar without *maesil* extract while maximum pH (4.22) was recorded with 105 g of *kochujang*, 30 g of *maesil* extract with white sugar (Table 2). Titratable acidity ranged from 15.63-32.88 mL. The relationship between the processing parameters and each response variable can be best understood by examining the response surfaces generated. Figure 1 and 2 show the response surface contours for pH and titratable acidity, respectively as a function of amount of *kochujang* and *maesil* extract used. The estimated response surfaces confirm that the amount of *maesil* extract has a negative and positive effect on pH and titratable acidity, respectively (Fig. 1 and 2). Similar results were reported for *kochujang* prepared with *maesil* extract Lee and Lee (2006) and this is probably due to organic acids contained in *maesil* itself (Choo and Shin, 2000). No significant differences in both pH and titratable acidity were found for samples made with different type of sugar.

Moisture content ranged from 52.40-75.47% and soluble solids content from 43.67-53.00°Brix, respectively

Table 2: The central composite experimental design with the observed responses

Independent variables			Responses						
Kochujang (g)	*Maesil* extract (g)	Sugar	pH	Titratable acidity (mL)	Moisture content (%)	Soluble solids content (°Brix)	Color L^*-value	a^*-value	b^*-value
1	1	1	3.81	25.17	53.69	51.57	27.86	14.67	11.39
-1	1	1	4.22	16.12	53.50	50.33	30.35	18.67	15.68
1	1	-1	3.74	25.20	52.40	53.00	28.64	15.72	12.65
1	-1	1	3.50	32.69	57.20	48.10	28.45	14.52	12.10
-1	-1	1	4.04	20.69	75.47	45.97	31.92	19.69	17.68
1	-1	-1	3.49	32.88	56.20	47.63	29.24	15.40	13.53
-1	1	-1	4.22	15.63	53.22	51.50	29.97	21.42	15.71
-1	-1	-1	4.04	20.73	58.98	43.67	32.43	20.54	18.61
0	0	0	3.83	23.92	54.17	49.63	30.68	18.82	14.19
0	0	0	3.83	22.90	54.30	49.17	29.69	18.63	14.51
1	0	0	3.63	28.35	54.80	50.53	29.14	16.08	13.45
0	0	1	3.84	24.01	55.83	49.87	30.05	17.36	14.74
0	1	0	3.93	20.78	53.66	51.70	29.28	19.79	14.58
-1	0	0	4.13	17.68	56.80	48.10	30.31	18.62	15.34
0	0	-1	3.83	24.45	55.76	50.20	31.64	20.19	17.52
0	-1	0	3.76	27.41	60.27	44.97	30.07	17.29	14.54

Table 3: Regression coefficients, R^2 and probability values for seven dependent variables for *chokochujang*

Coefficients	pH	Titratable acidity (mL)	Moisture content (%)	Soluble solids content (°Brix)	CIE color L^*-value	a^*-value	b^*-value
β_0	3.9748***	31.5756***	80.3954*	23.8322***	31.9861***	19.7494*	20.1444*
β_1	-0.0291***	0.6223***	-0.5541	0.2095*	-0.0703	-0.0318	-0.1071
β_2	0.0004	-0.1059*	-0.3116	0.2533**	0.0504	0.0212	0.0446
β_3	-0.0170	-2.0461	8.2667	-0.2000	-3.1350	-0.9843	-5.1519
β_{11}	0.0002*	-0.0034*	0.0023	-0.0002	-0.0021	-0.0054	-0.0030
β_{12}	0.0001*	-0.0010**	0.0038*	-0.0006*	0.0005	0.0001	0.0006
β_{22}	0.0001	0.0002	0.0008	-0.0005*	-0.0003	-0.0001	-0.0002
β_{13}	0.0007	-0.0056	-0.1207	-0.0174	-0.0120	0.0139	-0.0144
β_{23}	0.0002	0.0019	-0.0442	-0.0149*	0.0025	-0.0058	0.0030
β_{33}	-0.0022	0.4553	0.5224	0.6707	0.6528	0.2005	1.0698
R^2	0.9973	0.9977	0.8857	0.9864	0.9125	0.9146	0.8967
p or probability	0.0001	0.0001	0.0293	0.0001	0.0142	0.0132	0.0223

***Significant at $p = 0.001$, **Significant at $p = 0.01$, *Significant at $p = 0.05$

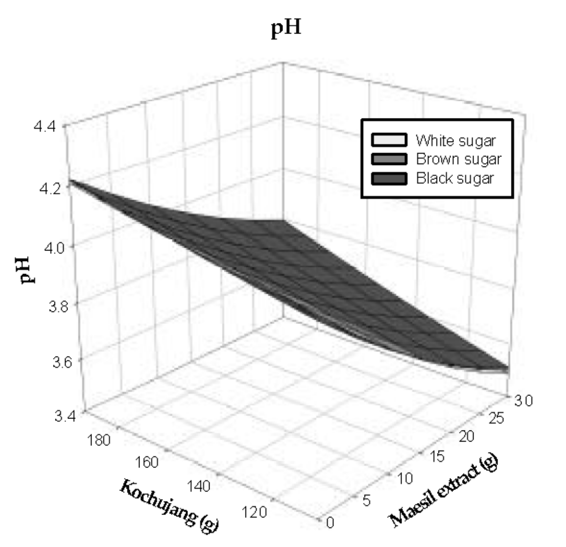

Fig. 1: Response surface contours for pH as a function of amount of *kochujang* and *maesil* extract

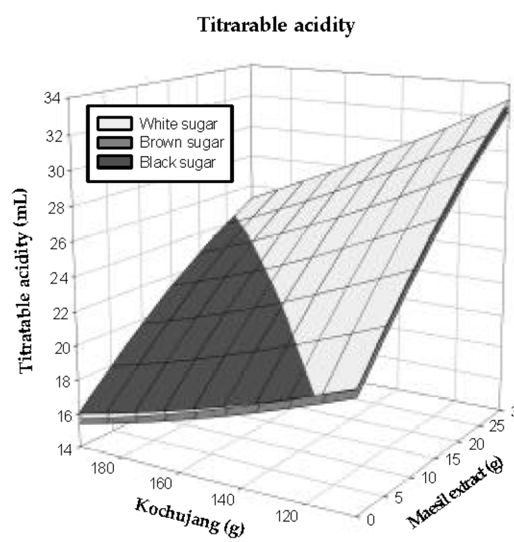

Fig. 2: Response surface contours for titratable acidity as a function of amount of *kochujang* and *maesil* extract

(Table 2). The estimated response surfaces show that the amount of *kochujang* and *maesil* extract have a negative effect on moisture content. It is interesting to note that type of sugar had a considerable influence on the moisture content. *Chokochujang* made with black sugar followed by brown sugar have higher moisture content than that made with white sugar. Kim *et al*. (2006) reported a significant difference in the moisture content of black rice cookies made with different type of sugar (*i.e.*, sucrose, aspartame and oligosaccarides). Soluble solids content increased significantly with increasing amount of *kochujang* in the sample but moderate increase due to *maesil* extract (Fig. 4). This is in agreement with the findings from Lee and Lee (2006) in *maesil kochujang* production. Again, the type of sugar used in *chokochujang* production did not have a significant influence on soluble solids content.

*L**-, *a**- and *b**-values ranged from 27.86-32.43, 14.52-21.42 and 11.39-18.61, respectively (Table 2). The amount of *maesil* extract has a negative effect on *L**-, *a**- and *b**-values (Fig. 5). This effect was more pronounced for *a**-value. The amount of *kochujang* did not appear to have a significant effect on those color parameters. On the contrary, type of sugar has a considerable effect on the color parameters. *Chokochujang* made with the black sugar showed lower *L**-, *a**- and *b**-values than the sample made with white

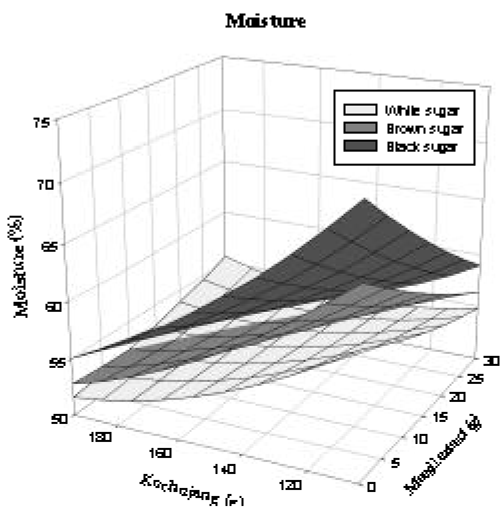

Fig. 3: Response surface contours for moisture content as a function of amount of *kochujang* and *maesil* extract

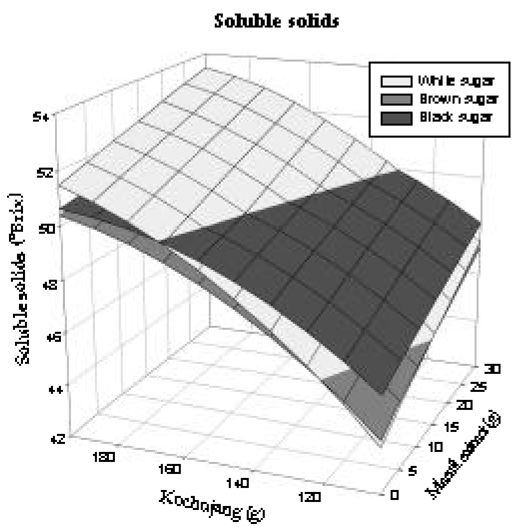

Fig. 4: Response surface contours for soluble solids content as a function of amount of *kochujang* and *maesil* extract

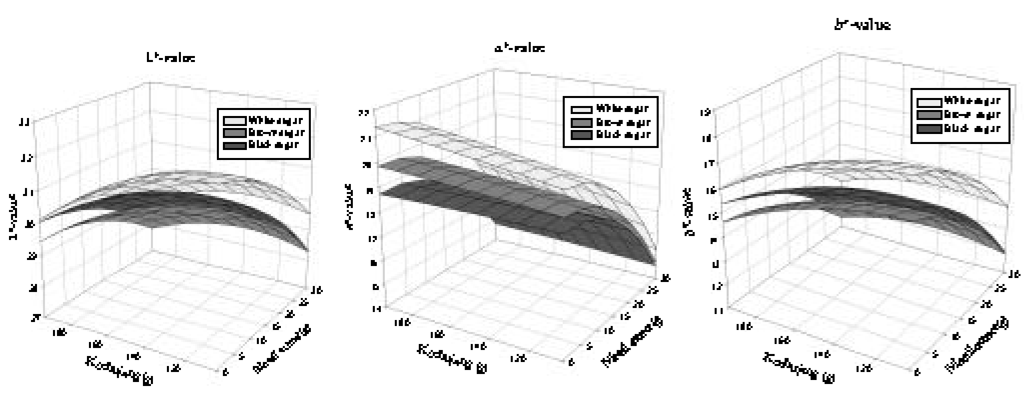

Fig. 5: Response surface contours for CIE color parameters as a function of amount of *kochujang* and *maesil* extract

sugar. Similar results with good agreement were reported by others (Lee and Lee, 2007; Lee *et al*., 2003; Park and Hong, 2003).

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