Optimization of sample preparation condition for meat laver production using response surface methodology

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***Abstract*— The meat laver which can be used for making rice rolls, was made from beef *semimembranosus* muscle instead of seaweed. The influence of three critical factors (sample cutting time (sec), drying temperature (˚C) and drying time (min)) was investigated in order to find the best conditions to make a meat laver using the response surface methodology. The complete designs consisted of 20 combinations (8 factorial points, 6 axial points and 6 centre points). A whole cut meat was speaded on a febric (15.0x16.0 cm) and dried in the oven. The combination of the sample cutting time (26.4-93.6 sec), drying temperature (46.6-63.4 ˚C), and drying time (78-138 min) was varied at design points of a central composite rotatable design. Significant regression models describing flexibility (cm, R_1), springiness (%, R_2) and contractility (%, R_3) were developed with the coefficient of determination greater than 0.8 (0.827, 0.837 and 0.834 for R_1, R_2 and R_3, respectively). The drying temperature of meat laver was the most significance determinant of all dependent variables in precipitate since those linear ($p<0.01$, $p<0.01$ and $p<0.05$ for R_1, R_2 and R_3, respectively) and quadratic ($p<0.001$, $p<0.01$ and $p<0.01$ for R_1, R_2 and R_3, respectively) effects mainly contributed to the total variation. The best combination of process variables was found to be the cutting time of 18.2 sec, drying temperature of 59.1 ˚C and drying time of 113.8 min. Under these conditions, the model gave predicted values of R_1, R_2 and R_3 being 2.24 cm, 167.95 % and 19.64 %, respectively.**

***Keywords*— Meat laver, RSM, Beef.**

I. INTRODUCTION

There are various types of rolled foods such as sushi roll, egg roll, rice roll, laver roll, vegetable roll or tofu skin roll around the world. Dried laver or rice paper among the foodstuff which can be wrapped around savory or sweet ingredients are especially used for making rolled food [1]. Thay are made from seaweed and rice flour, respectively and both of them are largely consumed in Asia [2, 3].

In the present study, meat laver (edible laver) was introduced as a new product made from meat (beef). Meat laver need mixing or emulsifying process for extraction of myofibrilar proteins and gelation by heat [4] in contrast to the making processes of rice paper which include wet-milling, fermentation, steaming and dehydration [3]. Therefore, sample cutting time accompanying mixing was used as one factor for processing condition, and dehydration condition (drying temperature and drying time) was also selected as main factors for making meat laver in this study. Response surface methodology (RSM) was used to optimize the conditions of the sample preparation and desirability function used as the methodology for the optimization.

II. MATERIALS AND METHODS

1. Materials and meat paper process

Minced beef (*Semimembranosus* m.) was cutted accompanying mixing using a mixer (Compact 3100, Magimix Co., Vignerons, France) for 13.2, 20.0, 30.0, 40.0 or 46.8 sec, respectively, and about 30.0 ± 0.02 g of cutted samples were spreaded on cheese cloths (16.5 x 15.0 cm) saperately. They were dried under the different drying conditions (temperature: 46.6, 50.0, 55.0, 60.0 or 63.4 ˚C; time: 78.0, 90.0, 108.0, 126.0 or 138, respectively) by using of drying oven (DS-80-1, Dasol Scientific Co., Hwasung, Korea).

2. Measurements

Flexibility (folding test, cm) was conducted by folding a 5.0 x 7.0 cm of meat laver, and the distence (cm) between both ends of sample were obtained when the creak develops immediately following pushing both ends of sample. This test indicates flexibility of meat laver: 0.0 cm, excessively flexible; 7.0 cm, excessively stiff. Samples (1.5x5 cm) were prepared for analysis of springiness following immersing into 100 ml of distilled water for 60 sec and quantified [5]. Force-time deformation curves were obtained with a 20 kg load cell applied at a cross-head speed of 2 mm/s using of Rheo-meter (Compac-100, Sun scientific Co., Tokyo, Japan). Contractility was evaluated by measuring the sample area before and after drying the meat laver sample: contractility (%) = (cm^2 sample area before drying – cm^2 sample area after drying) / (cm^2 sample area before drying) x 100.

3. Experimental design and statistical analysis

RSM was used to investigate the main effects of process variables (cutting time, X_1; drying temperature, X_2; drying time, X_3) on flexibility (R_1), springiness (R_2) and contractility (R_3) of meat lavers. A Central Composite Rotatable Design (CCRD) was used (Table 1).

Table 1. Expeimental values of response variables for CCRD

Run	Independent variables						Dependent variables		
	Coded level			Uncoded level			R1	R2	R3
	X1	X2	X3	A	B	C			
1	-1	-1	-1	20.0	50.0	90	0.5	110.0	11.8
2	-1	-1	+1	20.0	50.0	126	3.5	125.0	19.2
3	-1	+1	-1	20.0	60.0	90	4.1	105.0	14.6
4	-1	+1	+1	20.0	60.0	126	5.5	235.0	22.6
5	+1	-1	-1	40.0	50.0	90	0.0	84.2	12.3
6	+1	-1	+1	40.0	50.0	126	3.2	119.9	16.9
7	+1	+1	-1	40.0	60.0	90	5.1	109.0	17.5
8	+1	+1	+1	40.0	60.0	126	5.5	164.0	19.3
9	-1.68	0	0	13.2	55.0	108	1.8	159.0	20.5
10	1.68	0	0	46.8	55.0	108	5.0	127.0	16.3
11	0	-1.68	0	30.0	46.6	108	4.5	186.0	20.4
12	0	1.68	0	30.0	63.4	108	5.5	154.0	19.9
13	0	0	-1.68	30.0	55.0	78	0.5	39.6	8.6
14	0	0	1.68	30.0	55.0	138	2.8	209.0	22.2
15	0	0	0	30.0	55.0	108	2.8	89.0	14.6
16	0	0	0	30.0	55.0	108	0.7	58.1	11.0
17	0	0	0	30.0	55.0	108	0.5	95.0	14.7
18	0	0	0	30.0	55.0	108	3.0	46.0	10.4
19	0	0	0	30.0	55.0	108	4.2	64.0	15.7
20	0	0	0	30.0	55.0	108	0.5	76.4	12.2

Experimental data were fitted to a second order polynomial model and regression coefficients obtained [6].

$$Y = b_0 + \sum_{i=1}^{3} b_i X_i + \sum_{i=1}^{3} b_{ii} X_i^2 + \sum_{i<j=1}^{3} b_{ij} X_i X_j$$

: Y is dependent or response variable: b_0, b_i, b_{ii} and b_{ij} are intercept, linear, quadratic and interaction coefficie nts, respectively; and X_i and X_j are independent variab les.

III. RESULTS AND DISCUSSION

The coefficients of variables in the models caculated by the least square technique and their statistical significnaces were judged at a probability of 0.001, 0.01 or 0.05. R^2 values showed a good agreement between experimental data and predicted data for all regressions: 0.827, 0.837 and 0.834 for R^1, R^2 and R^3, respectively.

Table 2. Regression coefficients, R^2 and F-test provability for three dependent variables.

Regression coefficients [a]	Dependent variables [b]		
	R_1	R_2	R_3
b_0	40.497*	1298.798**	101.245*
b_1	0.437	14.008	1.092
b_2	1.163**	37.306**	2.908*
b_3	0.266	8.518	0.664
b_1^2	0.002*	0.078*	0.006*
b_2^2	0.010***	0.314**	0.024**
b_3^2	0.001	0.025	0.002
b_{12}	0.007	0.210	0.016
b_{13}	0.002*	0.058	0.005
b_{23}	0.004*	0.117	0.009
R^2	0.827	0.837	0.834
F-test probability	**	**	**

[a] Subscripts: 0, constant; 1, sample cutting time (sec); 2, drying temperature (˚C); 3, drying time (min).
[b] Dependent variables: R_1, flexibility (cm); R_2, springiness (%); R_3, contractility (%).
* Significant at 0.05; ** Significant at 0.01; *** Significant at 0.001.

As shown in Table 2, the drying temperature had a strong linear effects ($p<0.01$) on flexibility of meat laver. Quadratic terms of sample cutting time and drying temperature were significant ($p<0.05$). Also, interations both between sample cutting time and drying time and between drying temperature and drying time were significant at $p<0.05$. The relationship between three independent variables on flexibility is demonstrated in Fig. 1 which indicated that no maximum or minimum responses were present. It was observed that flexibility decreased linearly as drying temperature increased. However, flexibility were increased as increase of sample cutting time at the short drying time.

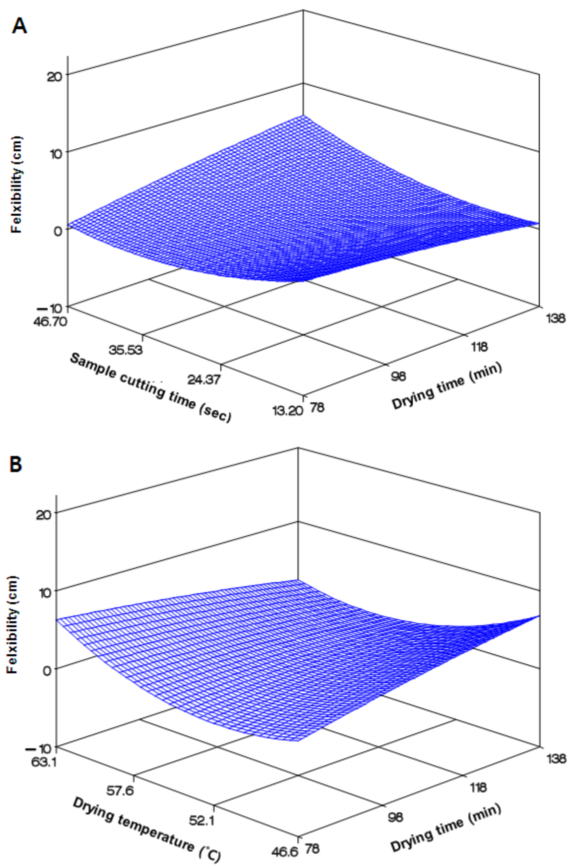

Fig. 1. Response surface graphs of flexibility (cm) at (A) drying temperature of 55.33 ˚C and (B) sample cutting time of 26.84 sec.

Springiness had significances in linear effect of drying temperature ($p<0.01$) and quadratic effects of sample cutting time ($p<0.05$) and drying temperature ($p<0.01$). As shown in Fig. 2, the behaviour of response surface graphs indicated that increasing drying temperature up to 56.2 ˚C had a negative effect on springiness in the meat laver. Springiness had a minimum value (45.87 %) at 30.62 sec of sample cutting time, 56.23 ˚C of drying temperature and 82.58 min of drying time.

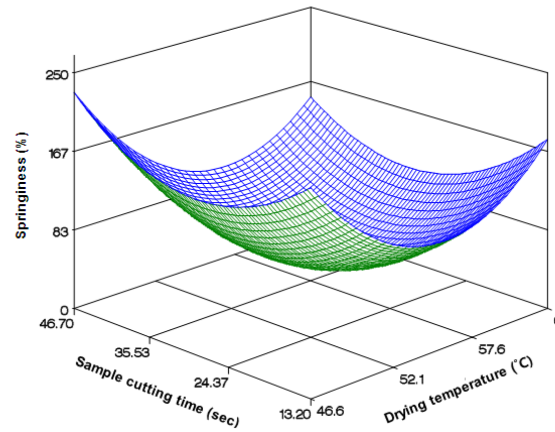

Fig. 2. Response surface graph of springiness (%) at drying time of 82.58 min.

Contractility had significnaces in linear effect of drying temperature ($p<0.05$) and quadratic effects of sample cutting time ($p<0.05$) and drying temperature ($p<0.01$). The minimum value of contractility (4.66 %) was predicted at 12.96 sec of sample cutting time, 52.55 ˚C of drying temperature and 11.00 min of drying time.

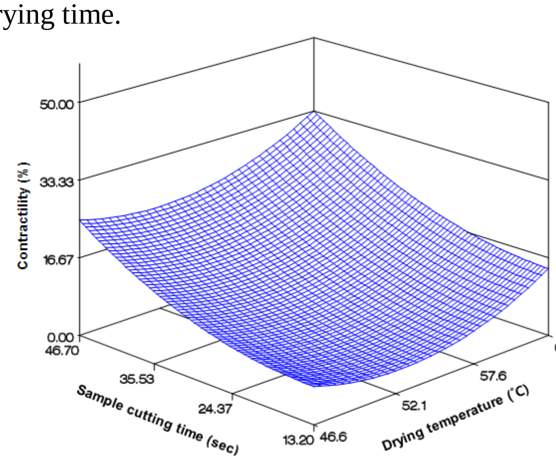

Fig. 3. Response surface graph of contractility (%) at drying time of 11.00 min.

The optimum precipitation conditions for sample preparation of meat laver were determined to obtain the criteria: minimum flexibility and contractility, and maximum springiness. Five solutions were obtained for the optimum covering criteria with desirability value of more than 0.877 (Table 3).

Table 3. Results of optimization by desirability function

#	desirability	X_1	X_2	X_3	R_1	R_2	R_3
1	0.892	18.2	59.1	113.8	2.24	167.95	19.64
2	0.883	15.2	57.6	113.2	2.26	168.59	19.88
3	0.879	26.2	60.6	118.0	2.20	167.60	19.40
4	0.878	17.2	58.6	114.2	2.17	169.04	19.78
5	0.877	32.2	53.6	138.0	2.17	165.54	19.53

X_1, sample cutting time (sec); X_2, drying temperature (˚C); X_3, drying time (min); R_1, flexibility (cm); R_2, springiness (%); R_3, contractility (%).

The best combination of variables was found to be sample cutting time of 18.2 sec, drying temperature of 59.1 ˚C and drying time of 113.8 min. At these conditions, the model gave predicted values of R_1 (flexibility), R_2 (springiness) and R_3 (contractility) being 2.24 cm, 167.95 % and 19.64 %, respectively.

IV. CONCLUSIONS

Drying temperature had significance in linear effect on response variables and quadratic effects of sample cutting time and drying temperature were significant on all the responses. The best combination of process variables was found to be the cutting time of 18.2 sec, drying temperature of 59.1 ˚C and drying time of 113.8 min. Under these conditions, the model gave predicted values of R_1, R_2 and R_3 being 2.24 cm, 167.95 % and 19.64 %, respectively.

ACKNOWLEDGMENT

This work is supported by Rural Development Administration and Kim G.D. & Jung E.Y. were supported by the Brain Korea 21 Project from Ministry of Education and Human Resources Development, Republic of Korea.

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